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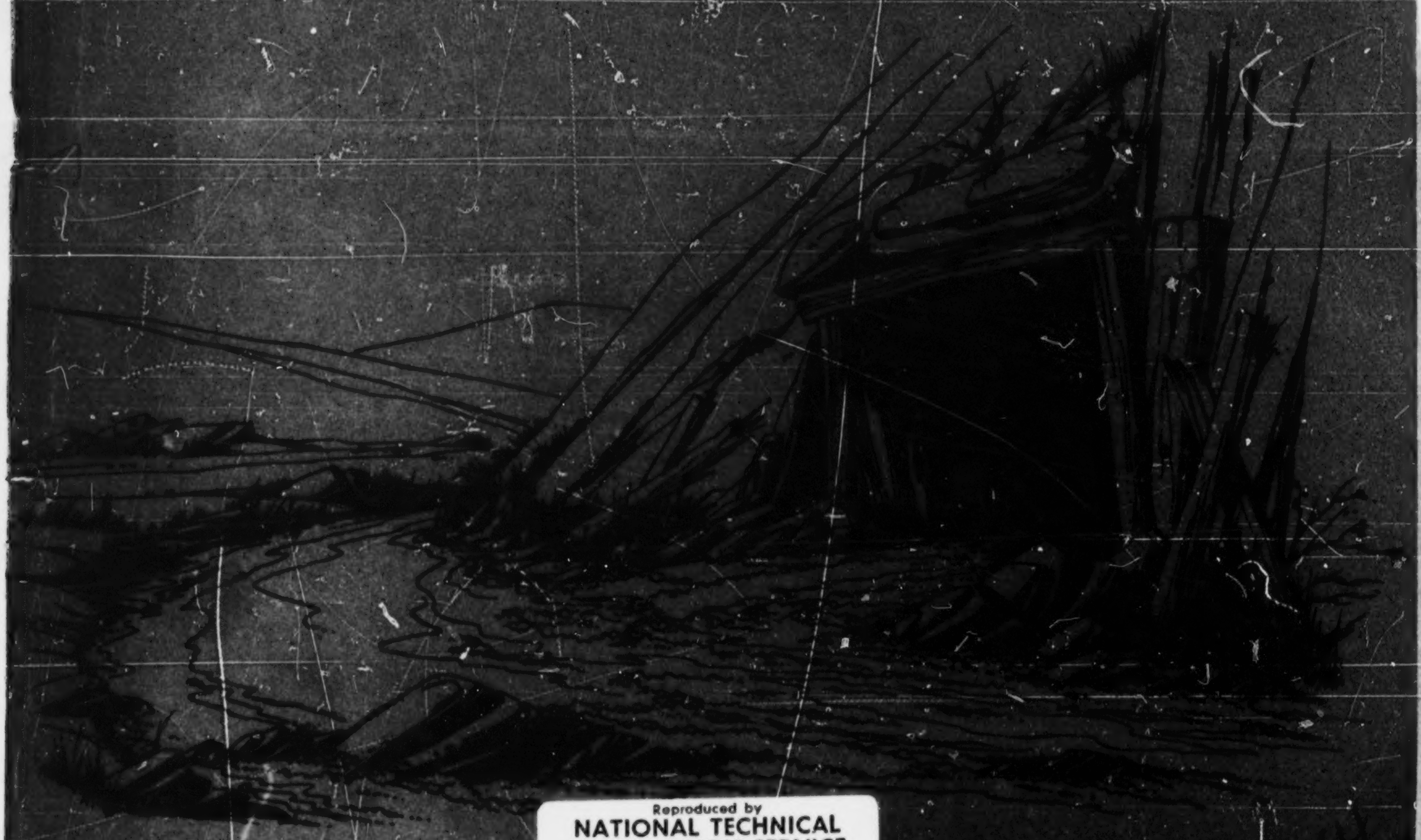
Control of Mine Drainage From Coal Mine Mineral Wastes



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27 *Abstract*

A project has been underway since 1968, at an abandoned mine located in southern Illinois, attempting to demonstrate practical means of abating pollution from coal mine mineral wastes. The site included a refuse pile occupying approximately 40 acres and a slurry lagoon complex of 50 acres.

The project consists of two phases. Phase I, reported herein, describes the characteristics and acid formation rate of the refuse pile. The average rate of acid formation for this refuse pile is 198 pounds of acidity, as $CaCO_3$, per acre per day. Acid contribution from the slurry lagoons was not determined but appears to be negligible.

As an abatement measure, a number of experimental vegetative covers were tested. Grass was successfully established with and without the use of topsoil, weathering well for one year. The long-term effects of establishing a grass cover directly on the refuse without the use of topsoil are not known at this time.

Phase II, currently in progress, will implement specific remedial procedures for the entire site, to be followed by a monitoring program that will determine the degree of pollution abatement. ~~A final report covering Phase II will be submitted.~~

(EPA abstract)

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Control of Mine Drainage From Coal Mine Mineral Wastes

PHASE I
HYDROLOGY AND RELATED EXPERIMENTS

by

Truax-Traer Coal Company
Pinckneyville, Illinois
A Division of
Consolidation Coal Company

for the

Environmental Protection Agency

Project No. 14010DDH

August, 1971

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ABSTRACT

A project has been underway since 1968, at an abandoned mine located in Southern Illinois, attempting to demonstrate practical means of abating pollution from coal mine mineral wastes. The site included a refuse pile occupying approximately 40 acres and a slurry lagoon complex of 50 acres.

The project consists of two phases. Phase I, reported herein, describes the characteristics and acid formation rate of the refuse pile. The average rate of acid formation for this refuse pile is 198 pounds of acidity, as $CaCO_3$, per acre per day. Acid contribution from the slurry lagoons was not determined but appears to be negligible.

As an abatement measure, a number of experimental vegetative covers were tested. Grass was successfully established with and without the use of topsoil, weathering well for one year. The long-term effects of establishing a grass cover directly on the refuse without the use of topsoil are not known at this time.

Phase II, currently in progress, will implement specific remedial procedures for the entire site, to be followed by a monitoring program that will determine the degree of pollution abatement. A final report covering Phase II will be submitted.

This report was submitted in partial fulfillment of Project Number 14010DDH under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

Key words: Mine drainage, refuse piles, slurry lagoons, New Kathleen Mine, vegetative covers, mineral wastes, acid formation rate, Illinois, grasses, reclamation.

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CONCLUSIONS

1. The 40-acre refuse pile under investigation can be regarded as being reactive primarily at the surface exposed to the atmosphere, the zone of reaction extending approximately 4 inches into the pile, but spreading up to 24 inches in depth in noncompacted areas. Between rains, the pyrite oxidation reaction proceeds on the refuse pile at a relatively constant rate, with the acid products accumulating in the outer reactive mantle. When precipitation occurs, approximately 54% of the rainfall appears immediately as an acidic runoff, while the remainder either infiltrates into the interior of the pile, reappearing later as seepage, or eventually returns to the atmosphere by evaporation.

2. The average rate of acid formation for this particular refuse pile is 198 pounds of acidity, as $CaCO_3$, per acre per day.

3. Erosion during periods of precipitation constantly renews the reactive mantle and, in its present state, the refuse pile can be expected to produce acid at a relatively constant rate until it is completely eroded away or effective abatement procedures are developed or adopted.

4. The acid contribution from the slurry lagoons to the surface streams at this site was not determined but appears to be negligible, based on observations in Walker Creek, primarily because the slurry lagoon area is completely enclosed by dikes. However, during dry weather, the slurry lagoons create an air pollution problem due to the very small particle size of the material deposited therein. Blowing winds entrain the surface material and deposit dust in the vicinity of the site.

5. Vegetative covers can be established, as an abatement measure, on highly acidic mineral wastes, with and without the use of topsoil. Stands of dense grass were established on 0.1 acre test plots weathering well for one year. The key to successful establishment of a grass cover directly on the refuse pile without any external topsoil appears to be the application of sufficient quantities of agricultural limestone to raise the pH of the material into a zone capable of supporting vegetation ($pH > 5$) followed by proper addition of fertilizer.

6. The long-term effects of establishing a grass cover directly on the mineral wastes without the use of topsoil

are not known at this time. Whether a stand of grass will sustain itself after an initial treatment or whether it will be necessary to apply limestone and fertilizer again, and for how long, is unknown.

7. Severe corrosion problems were experienced with the steel flumes used in conjunction with the flow measurements from the refuse pile. Although these problems were eventually brought under control by the installation of stainless steel liners, some water loss probably occurred throughout the course of the study.

RECOMMENDATIONS

1. The estimation of acid formation rates from hydrologic and water quality data should be further investigated for other refuse piles.

2. An essentially complete water balance should be made to further characterize the pyrite oxidation system and should include a study of the infiltrated water and evaporation as related to acid formation. Such data could then be used with a greater degree of confidence in selecting the optimum alternatives for remedial action.

3. Additional studies are required to better correlate acidity with conductivity.

4. Less conservative pollution abatement procedures should be investigated and their effectiveness determined over a relatively long period of time, say five years. Organic, chemical, and mechanical abatement techniques that appear promising should be tested on large demonstration plots, say 25 acres minimum.

5. Among the more promising abatement techniques recommended for further study on large demonstration plots are the application of vegetative covers directly on refuse piles after treatment with limestone and/or with minimum thickness of topsoil.

6. Additional research is needed in the area of chemical characterization of coal mining mineral wastes preparatory to implementing abatement procedures of the vegetative cover type. Conventional soil tests, used in the agricultural industry, cannot be used because of the reactive nature of acid-forming pyrite.

7. Additional research is needed to determine the minimum thickness of topsoil required to provide a suitable environment for germination, growth, and survival of vegetative covers established on coal mining mineral wastes.

8. Chemical stabilizers and mechanical covers should be investigated to broaden the knowledge of these pollution abatement techniques. Thus, industry would have available a large number of options from which to make a rational selection to abate pollution from coal mining mineral wastes.

INTRODUCTION

A substantial amount of coal mined in this country undergoes a beneficiation or a cleaning operation. This is done to remove some of the dirt and impurities present in the coal. These impurities form the rejects or unmarketable portion of the coal mining operations and are usually referred to as "refuse" or "gob".

Disposal of the refuse varies with the type of mining operations conducted, i.e., surface or underground. When coal from a surface mine is cleaned, modern practice frequently consists of trucking the refuse back to the strip pits to be buried in the spoil bank under an adequate thickness of overburden material. The land is then graded and planted with a suitable cover of grass, shrubs, or trees.

When a coal cleaning operation is practiced in conjunction with an underground mine, the disposal of refuse becomes a more complex problem. Since strip pits are not normally available to an underground mine, disposal of the larger pieces of refuse, up to 8 inches in diameter, is to the nearest open field or valley. Fine reject material, usually 20 mesh and smaller, is transported in slurry form, by pipeline, to diked enclosures, slurry lagoons, or surface impoundments.

The coarse refuse portion of a coal cleaning operation consists largely of coal intermixed with pyrites, sandstones, clays, and shales of a carbonaceous character. When stored outdoors in piles or heaps and exposed to the elements, chemical reactions take place on the surface of the refuse pile. Rainfall, oxygen in the air, and the pyrite in the refuse provide an ideal environment for the formation of an acidic drainage containing dissolved iron and other compounds which enters the streams and rivers from runoff and seepage through the pile. Additional problems follow in that the clays, shales, and sandstones are continuously decomposed and erosion constantly washes away the silt, exposing new material for oxidation and acid formation. Acid drainage and siltation occur during mining operations, and can continue for decades after operations cease.

Slurry lagoons associated with coal mining operations present a different type of environmental problem. The lagoons contain the fine reject material from a cleaning plant and can analyze as much as 50% coal with the balance ash and some pyrite. Rainfall on these lagoons percolates

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into the beds, seeps through the dikes, or is returned to the atmosphere via evaporation, with little surface runoff. The dikes are usually well built and compacted from clean earth, but occasionally are built from refuse and covered with a layer of earth. In many instances, a grass cover or trees are planted on the slopes to prevent erosion, or vegetation can develop from volunteer growth. During active operations, a pool of water exists on the surface and only minor problems are experienced involving repairs to a leaking dike. When mining operations cease, maintenance often ceases and the dikes can wash out during heavy rainstorms. In addition, during extended periods of dry weather, blowing winds entrain the surface material and create a dust problem in the vicinity of the site.

Scores of these types of refuse piles and slurry lagoons, from undergound and surface mining operations, exist in both the Appalachian and Midwestern coal fields. To date, only a limited number of options are available to effectively handle this problem. Topography tends to make each situation unique. In a large number of instances, the refuse piles have been abandoned.

In some instances, covering the pile with a thick layer of clean earth and planting a vegetative cover has been effective but very expensive. As an example, current requirements in Illinois[1]* require a four-foot thickness of clean earth to be applied to a new refuse pile, followed by a vegetative cover to prevent erosion and exposure of the refuse pile to the elements. In certain cases, earth cover may not be available or it may be so expensive as to make the covering operation very costly. Chemical treatment of the runoff and seepage, using hydrated lime or limestone, may be an interim measure during active operations but is obviously not the long-term solution since the formation of acid can continue for decades.

In the latter part of 1968, Truax-Traer Coal Company, a Division of Consolidation Coal Company, entered into a cooperative grant with the Federal Water Pollution Control Administration to demonstrate effective and practical means of abating air and water pollution from coal mining refuse piles and slurry lagoons. The intention of this demonstration project was to provide engineering data and design parameters that could be applied to minimize or prevent these types of pollution. The project would thus allow the knowledge on this subject to be advanced a stage further by providing design data and field experience for which there was and is an industrywide need.

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*References are found in the back of the report

The specific site chosen for this project was an abandoned mining operation, formerly known as the New Kathleen Mine, located in Southern Illinois and active from 1943-1955. This site consisted of a refuse pile occupying approximately 40 acres and an adjacent slurry lagoon complex consisting of 50 acres.

The project is divided into two phases. Phase I consists of determining the system characteristics and acid formation rate of the refuse pile and testing potential abatement measures for both the refuse pile and slurry lagoons. Phase II, currently in progress, will implement specific remedial procedures for the entire demonstration site to be followed by a monitoring program that will evaluate the degree of pollution abatement. This report presents the results of Phase I. A final report covering Phase II will be submitted.

The Water Resources Center of The Ohio State University was selected as subcontractor to Consolidation Coal Company and acts as technical consultant to the project, providing guidance and interpreting data on hydrology and acid formation.

DESCRIPTION OF SITE

The New Kathleen Mine site, the subject of this study, is located approximately five miles southwest of DuQuoin, Illinois, on typical midwestern flatlands, surrounded by agricultural operations, with surface mining activities, both active and abandoned, in close proximity, Figure 1.

The site forms a part of an abandoned coal mining operation, active from 1943-1955, that included a coal cleaning plant operated by Union Collieries Company in conjunction with the New Kathleen Mine. This was a slope mine in the Herrin (No. 6) Seam at a depth of approximately 110 feet.

Surface drainage from the site is generally to the west, into Walker Creek which flows southwest past the western end of the pile and which has its headwaters approximately one-half mile north of the pile. Flow in Walker Creek often ceases during the dry summer months.

The site contained an irregularly shaped refuse pile approximately 40 acres in area, standing 65 feet at its highest point and containing about 2,000,000 cubic yards of coarse refuse. In addition to the refuse pile, the site contained a complex of six slurry lagoons, standing approximately 15 feet high, essentially flat, and occupying some 50 acres in area, Figure 2. The lagoons were completely enclosed by earthen dikes and contained the fine coal rejects transported thereto by hydraulic means. At the west end of the slurry lagoons, six small lakes remained from the abandoned mining operations that were used to collect the runoff from the slurry lagoons, and so arranged as to eventually overflow into Walker Creek. The refuse pile and slurry lagoons were separated by a strip of original ground, approximately 1,500 feet wide, that was used for a railroad siding during the active mining operations. The material in the refuse pile was a mixture of shale, clay, and low-grade coal, in which both sulfur ball and large-crystal pyrite forms were included. The composite material was sufficiently cohesive to stand at an angle of repose nearly vertical, but it was very susceptible to erosion, as reflected in the deep gullies which were formed on the side slopes of the pile, Figure 3. The refuse material throughout the pile appeared to be heterogeneous in its physical characteristics, reflecting the irregular manner in which the pile was formed. Much of the pile was placed by end-dumping from trucks.

Further examination revealed a relatively large number of individual seepage points at the base of the refuse pile.

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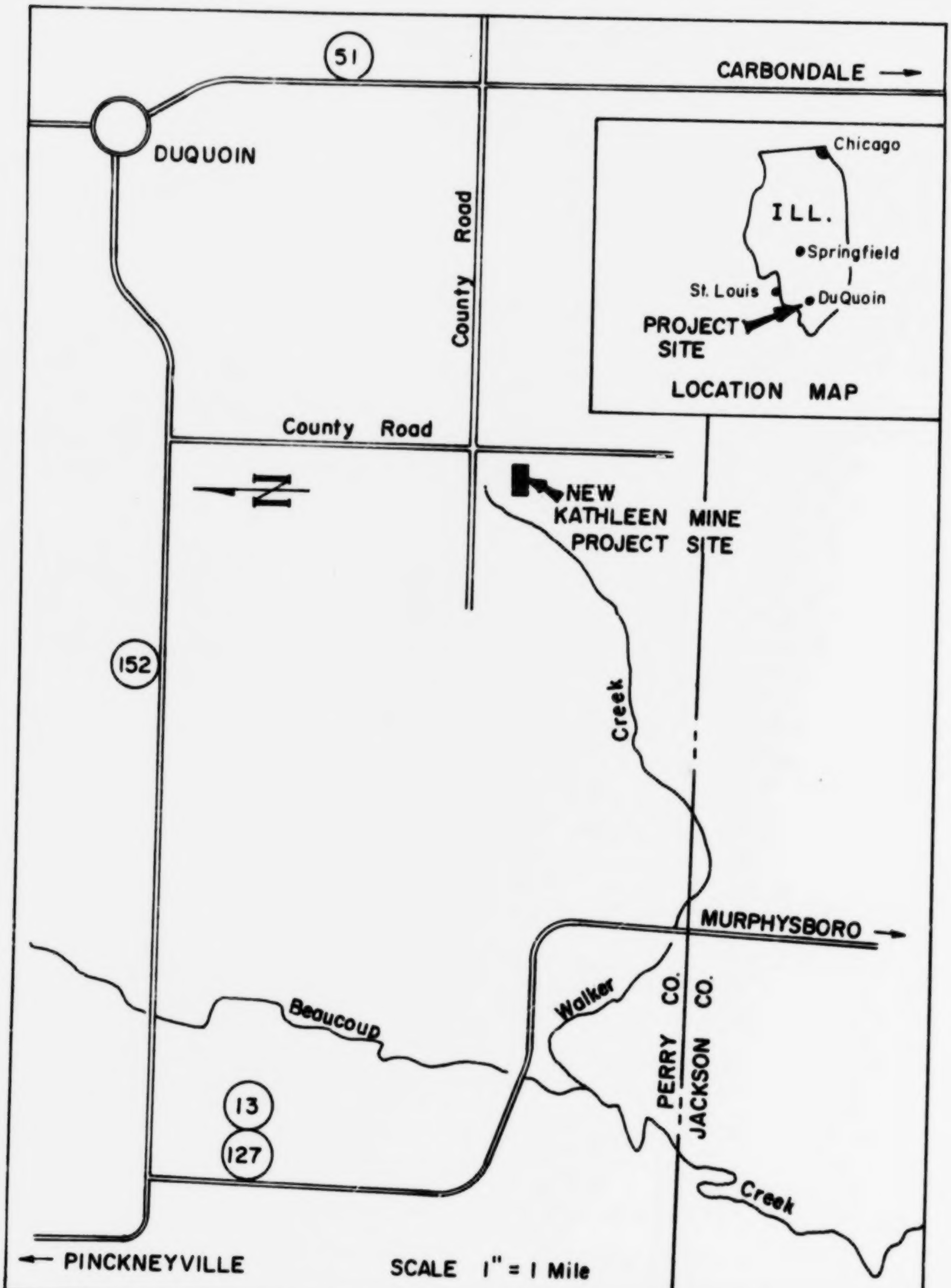


51
CARBONDALE →
DUQUOIN
County Road
County Road
Chicago
ILL.
Springfield
St. Louis
DuQuoin
PROJECT SITE
LOCATION MAP
N
NEW KATHLEEN MINE PROJECT SITE
152
Creek
MURPHYSBORO →
Walker
Beaucoup
PERRY CO.
JACKSON CO.
13
127
Creek
← PINCKNEYVILLE
SCALE 1" = 1 Mile

FIG. 1 NEW KATHLEEN MINE DU QUOIN, ILLINOIS

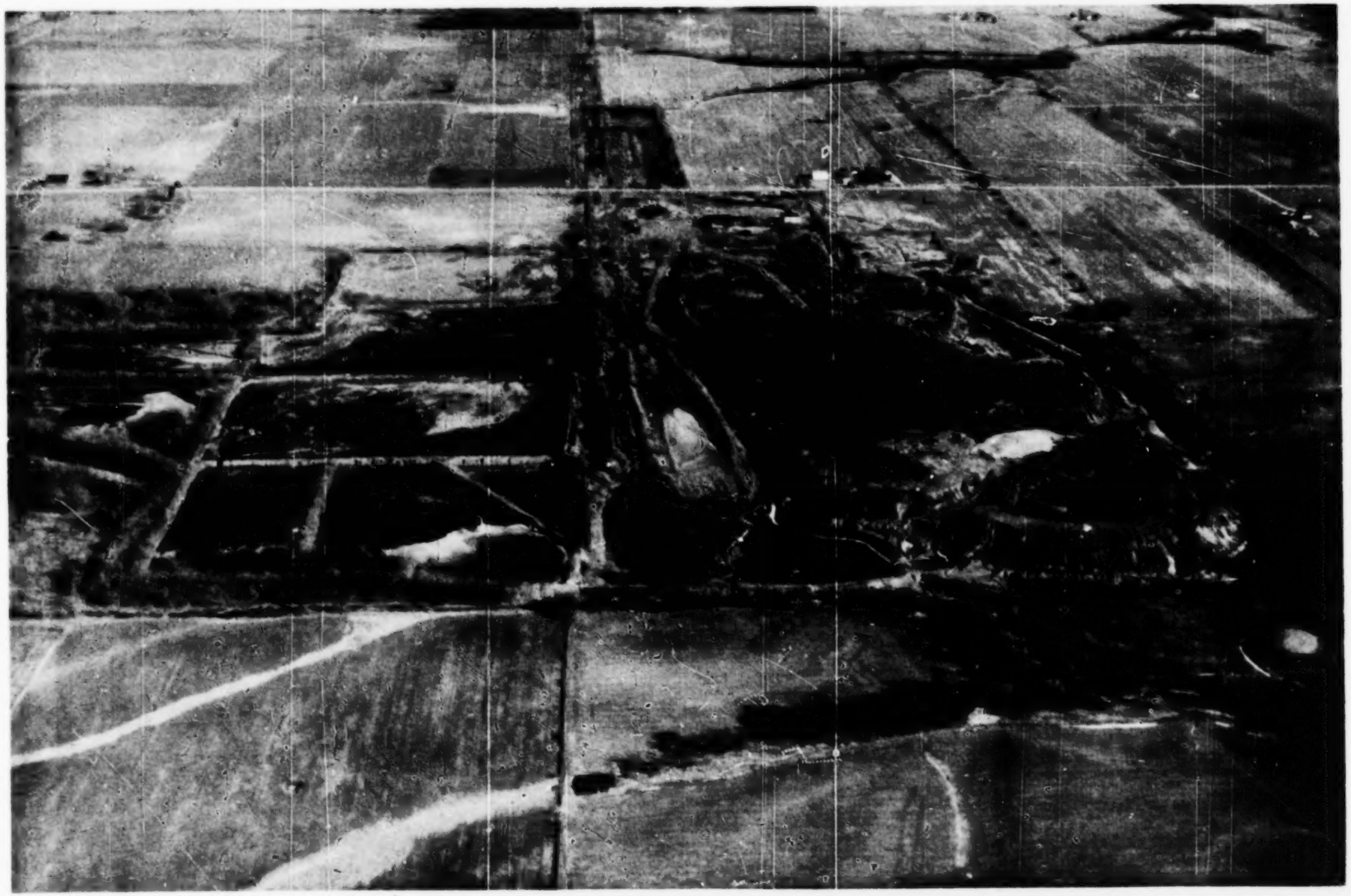


FIG. 2 AERIAL VIEW OF NEW KATHLEEN MINE

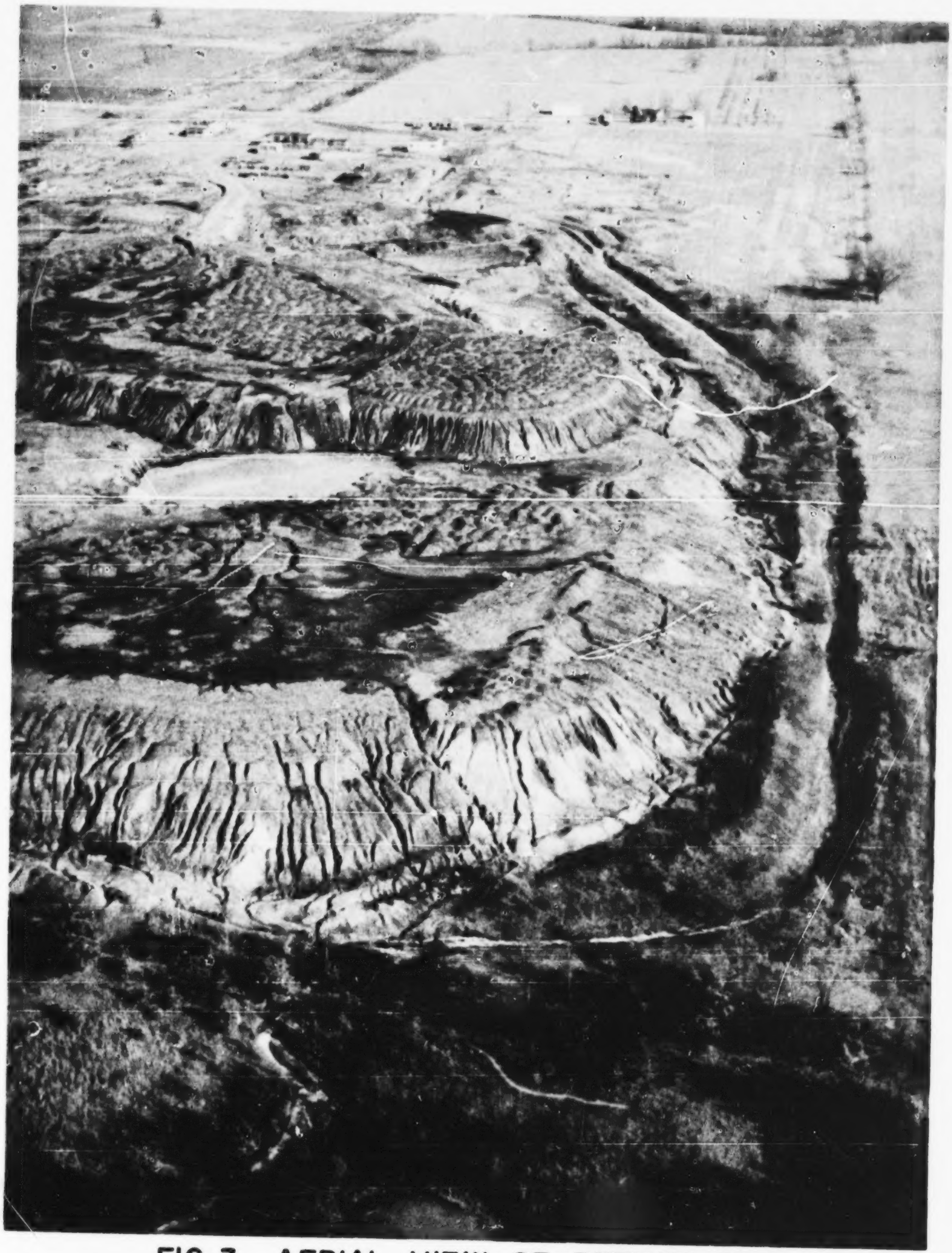


FIG. 3 AERIAL VIEW OF REFUSE PILE

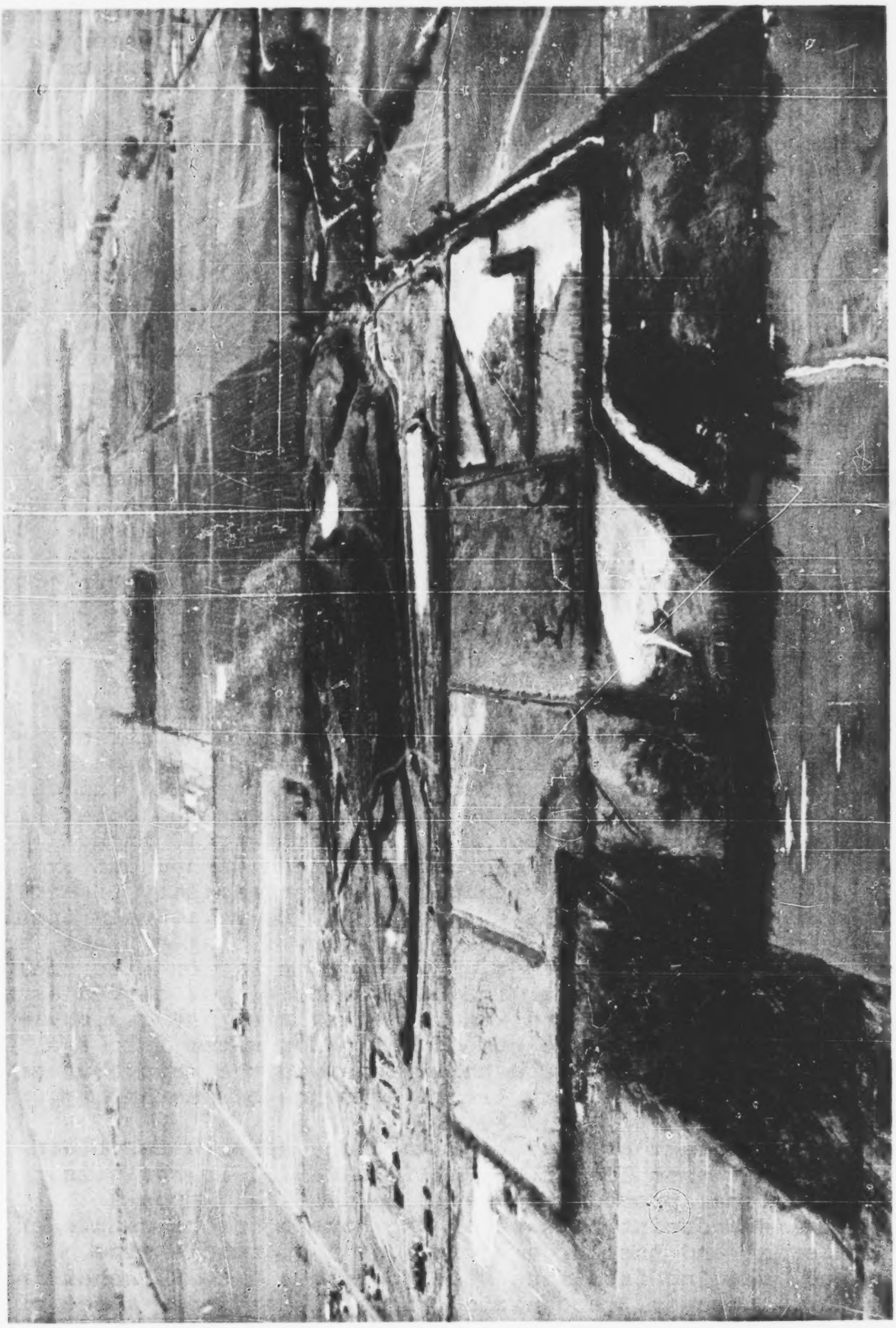


FIG. 4 AERIAL VIEW OF SLURRY LAGOON AREA

Some were continuous flows while others appeared to be intermittent, indicating either a storage pool of water existed in the pile or parts of the pile were resting on ground water springs, or both.

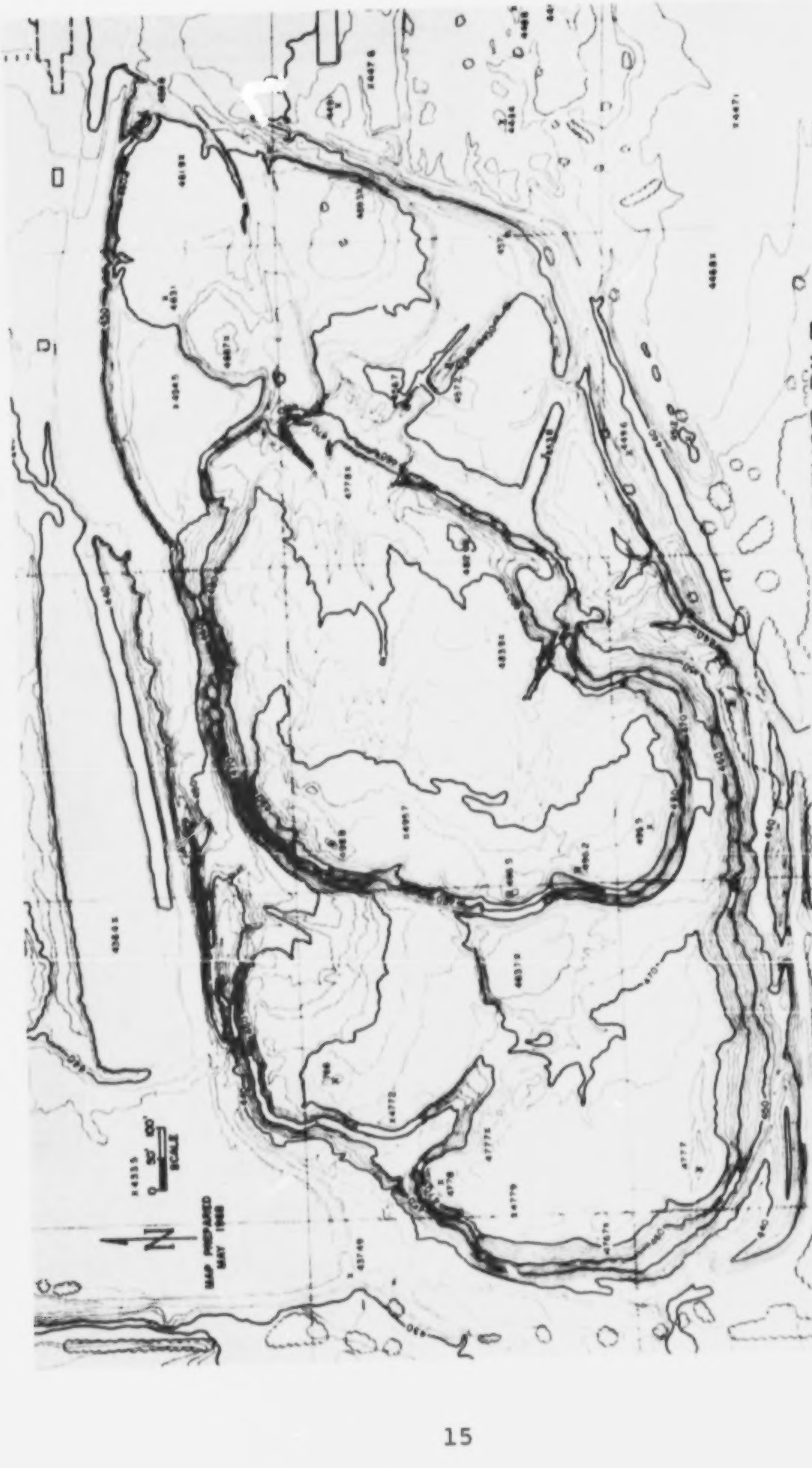
Portions of the western one-third of the pile showed evidence of burning at some time in the past.

Both the refuse pile and the slurry lagoons were essentially barren except for the eastern edge of the slurry lagoons, where volunteer growth was established on soil, apparently washed down from the top of the dikes. Vegetation in the form of trees, grass, and shrubs was established on the outer periphery of the slurry lagoon area, Figure 4.

An aerial survey of the site was made from which contour maps were prepared. These are shown in Figure 5 and Figure 6. Reference to Figure 5 shows the natural division of the refuse pile into three sections. The western one-third features a plateau with a surface elevation of about 470 feet, relative to an original ground elevation of about 430 feet. The central, and highest section of the pile has an elevation of somewhat more than 490 feet at its western edge, and slopes toward the east to an elevation of about 475 feet, where there is an abrupt drop to the eastern one-third of the pile.

To develop a better understanding of the pile structure below the surface, a backhoe was used to cut a number of trenches in several sections of the pile to a depth of 8 feet. Examination of the cross section of the pile indicated three distinct layers or zones. The first was the outer mantle of the pile, consisting of a layer 4 to 10 inches thick, from which much of the clay had been washed out by precipitation. From the standpoint of permeability to air and water, this outer mantle appeared to be relatively open. The second zone was comprised of a layer of clayey fines, an inch or more thick, packed tightly by rain action into the refuse immediately beneath the outer mantle that served as a partial barrier to air and water. This layer had discontinuities which provided points of entry for water into the main body of the pile. The third zone was the main body of the pile which showed only little evidence of weathering.

It became apparent at that time that any efforts to obtain representative samples of the solid material in the pile, using classical procedures, would be difficult from a practical standpoint because of the heterogeneous nature of the material and the large variations in particle size observed, ranging from fine silt to pieces 6 to 8 inches in diameter. However, recognizing these limitations, a set of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MAP PREPARED
MAY 1968
0 50' 100'
SCALE

FIGURE 5 CONTOUR MAP OF REFUSE PILE

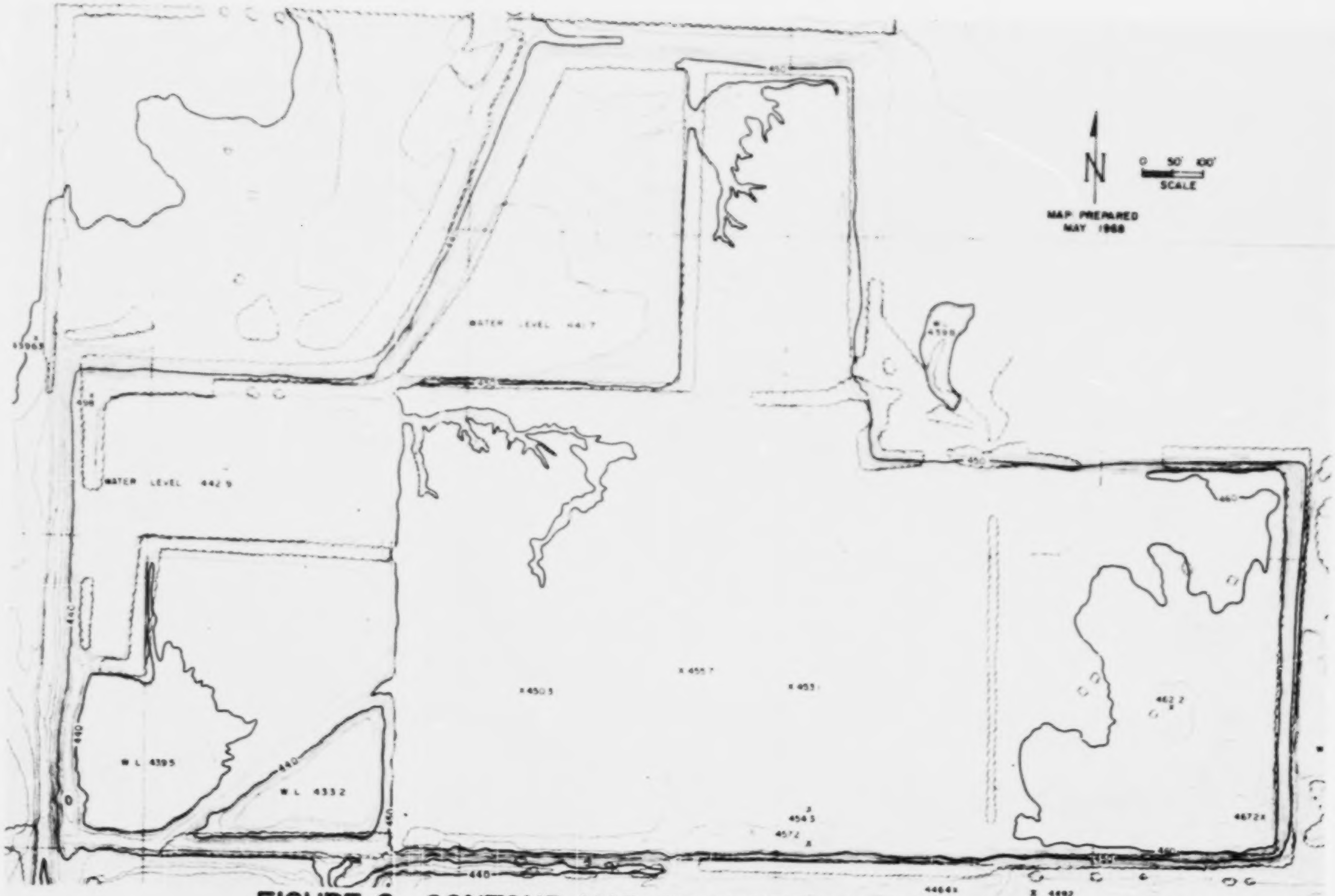
N
0 50' 100'
SCALE
MAP PREPARED
MAY 1968
WATER LEVEL 441.7
WATER LEVEL 442.9
W.L. 439.5
W.L. 433.2
440
450
460
4596.8
x 450.3
x 455.7
x 453.1
454.5
457.2
462.2
4672x
4464x
x 4492

FIGURE 6 CONTOUR MAP OF SLURRY LAGOON AREA

random samples was taken from the top 4 inches of the refuse pile and analyzed for sulfur forms and total sulfur. The results are shown in Table I.

TABLE I. FORMS OF SULFUR ON
REFUSE PILE IN UPPER 4-INCH LAYER

Sample No.	% Totals	% Sulfates	% Pyritics	% Organics
1	5.51	4.83	0.029	0.65
2	9.12	3.36	4.08	1.68
3	14.05	3.27	10.60	0.18
4	14.02	2.73	9.78	1.51
5	7.77	3.07	3.70	1.00
6	5.35	3.94	0.72	0.69
7	5.82	5.05	0.078	0.69

Soil Type Composition of
Composite of Above Seven Samples

Clay: 34.7%
Carbonaceous material: 37.8%
Shales, other coarse non-carbonaceous material: 27.5%

All analyses reported on a dry weight basis.

OBJECTIVES

The main objective of this demonstration project was to develop a realistic understanding of the factors associated with acid formation and runoff from coal refuse piles and slurry lagoons so that rational pollution abatement techniques could be developed and applied elsewhere to similar environmental problems.

More specifically, the intention of this project was to provide engineering data and design parameters that, when applied, would minimize or prevent this type of acid pollution.

The immediate objectives of this program were:

1. To determine the acid formation rate of the refuse pile.
2. To explore the effectiveness of specific abatement procedures for this site.

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ACID FORMATION RATE STUDIES

Strategy for Action

The visual examination of the refuse pile cross sections formed the basis for the hypothesis used in determining the acid formation rate of the pile. It was postulated that acid formation, i.e., the oxidation of pyrite, was confined to a relatively narrow zone at or near the surface with the products of the reaction accumulating in this zone. During periods of precipitation, a portion of these products was flushed out and appeared in the surface runoff while the remainder percolated into the interior, appearing later as seepage at the base of the pile eventually entering Walker Creek.

Two approaches to determining the acid formation rate from the pile were considered. The first consisted of a direct measurement of the total amount of acid leaving the pile, which could be obtained by measuring the drainage flow and acidity at a single point receiving all the flows from the pile. If measured over an extended period of time, preferably one water year, the total acid formation rate could be thus determined. After due consideration, this approach was abandoned because of practical problems involving property limitations, excavation, and construction difficulties associated with collecting all the drainage at a single point.

As an alternative approach, consideration was given to dividing the refuse pile into six watersheds and monitoring the surface runoff from each watershed. Seepage into and out of the pile, plus the evaporation effect, would then have to be related to the rainfall and surface runoff before an average acid formation rate could be determined. This alternative approach, with certain modifications, was used in the study.

Installation and Operation of Monitoring Stations

The situation at the site was favorable for the determination of a hydrologic water balance around the refuse pile in that the only water input to the area was in the form of precipitation. The pile rests near the headwaters of Walker Creek and is located at an elevation sufficient to prevent either ground or surface water from entering the refuse pile. A water balance around the pile would have consisted of rainfall on the pile, direct runoff, seepage from within the pile, and evaporation.

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Rainfall was measured by a single continuous bucket recorder type rain gage. This instrument was located approximately 500 feet east of the pile. No problems were experienced with this instrument and the measurements were considered satisfactory with respect to rainfall on the pile.

Although it appeared feasible initially to measure surface runoff from the pile by installing six monitoring stations, additional construction problems prevented the installation of all six. Instead, sections of the refuse pile were shaped, with a minimum amount of grading, into three watersheds from which runoff and water quality data could be obtained. Flumes were sized and installed to monitor surface runoff from the three areas shown in Figure 7 (Areas 1, 2, and 6). H-type flumes as described in U.S. Department of Agriculture hydrology field manual[2] were used. An error in construction of the 1.5-foot flume in Area 6 required the calibration of this flume in the field and the revised rating table is given in Appendix XI-B. The 3.0-foot flume in Area 1 had a flume section constructed of stainless steel, while the other two were constructed of Corten steel. The drop boxes of all three flumes were constructed of mild steel. Each flume was equipped with a water level recorder to measure surface runoff. Severe corrosion was experienced with the Corten flumes and with the drop boxes for all three flumes, in spite of attempts to protect them with asphalt mastics. Although the corrosion problems were brought under control by August, 1969 by the installation of stainless steel liners, some water loss probably occurred at the Area 1 and Area 2 flumes throughout the course of the study.

Siltation in the drop boxes of the flumes and stage recorder float chambers created a continuous maintenance problem. A single storm of sufficient duration could completely fill these units with silt. Manual removal of the silt with shovels after the storm was the most practical way of handling this problem.

In December, 1969, a three-point continuous temperature recorder was installed near the flume in Area 6. A continuous record of ambient temperature, temperature 2 inches below the surface, and 20 inches below the surface was obtained.

During all of 1969, water quality samples were taken by hand at approximately 2-minute intervals throughout the duration of a rain storm. Samples were analyzed at the on-site laboratory for pH, acidity, total alkalinity, ferrous and total iron, and sulfate. The acidity values, together with the runoff data obtained at the flumes, were used to calculate the mass flow of acid flowing from each of the monitored areas. While this procedure was very accurate, it required considerable amounts of manpower, and storms occurring during

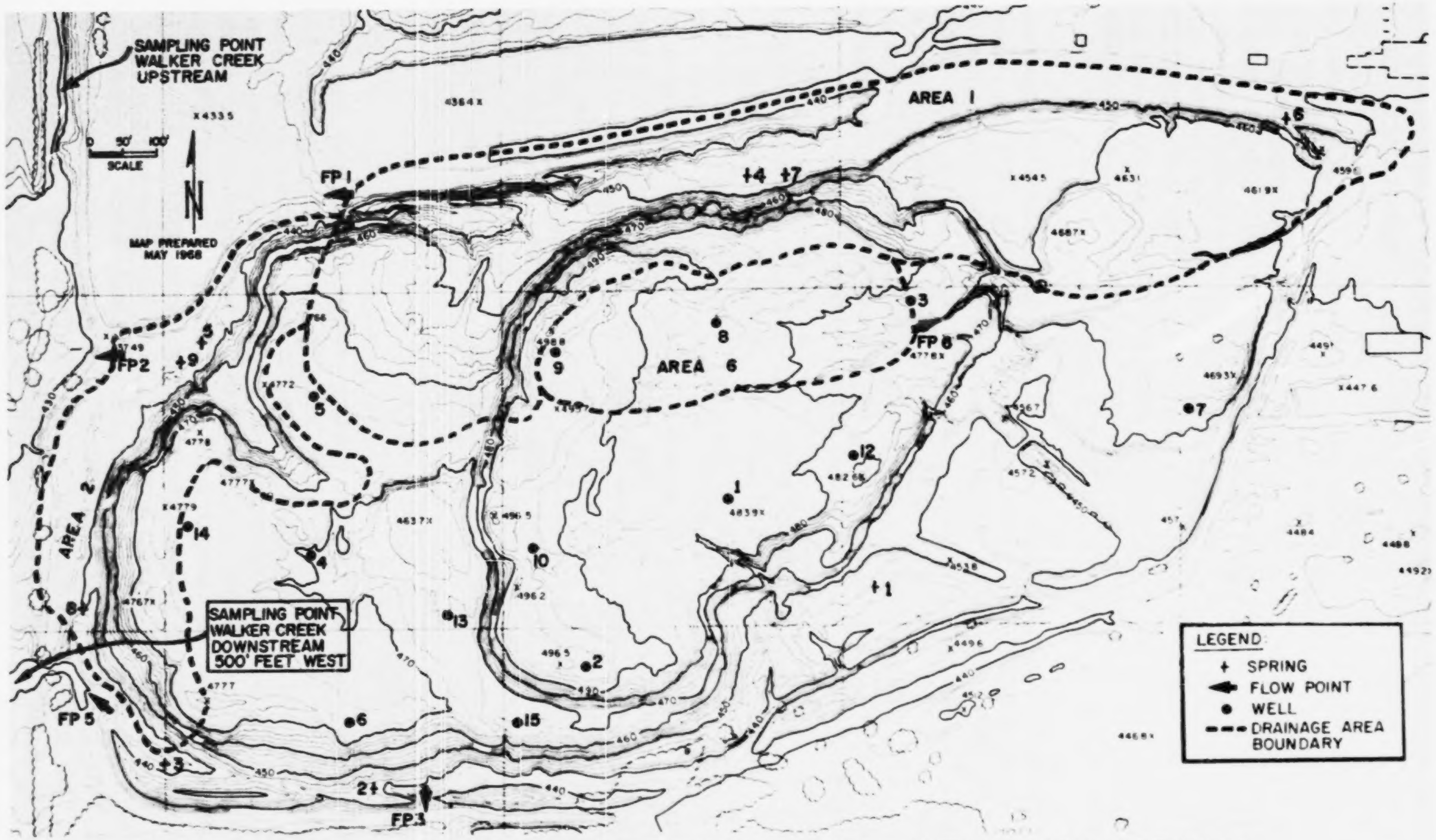
SAMPLING POINT
WALKER CREEK
UPSTREAM
0 50' 100'
SCALE
N
MAP PREPARED
MAY 1968
AREA 1
AREA 2
AREA 6
FP 1
FP 2
FP 3
FP 5
FP 6
SAMPLING POINT
WALKER CREEK
DOWNSTREAM
500' FEET WEST
LEGEND:
SPRING
FLOW POINT
WELL
DRAINAGE AREA
BOUNDARY

FIGURE 7 FLOW MONITORING POINTS - WELLS AND SPRINGS

unattended periods could not be effectively monitored. Experiments conducted with a laboratory conductivity meter showed a correlation between total acidity and conductivity for any given flow point (data in Appendix XI-F). However, separate correlations for each flow point were necessary. Based on these correlations, portable battery-operated recording conductivity meters were installed at the three monitoring flumes in January, 1970. Meter readings were correlated regularly with acidity analyses to provide a basis for the estimation of acidity concentrations from the conductivity record during a period of storm runoff. All storms monitored in 1970 used conductivity measurements as a basis for estimating the acidity values in the runoff.

Notwithstanding manufacturer's claims, the battery-operated conductivity meters did not function satisfactorily. Leak-proof batteries leaked and the response of the instrument was sluggish in cold weather. In January, 1970, the conductivity meter installed in Area 6 was converted to operate on 110 V. AC and this proved to be very satisfactory. The other two meters continued to operate on batteries for the duration of the data collection period, i.e., Phase I.

The final item in the hydrologic water balance was evaporation. In this system, evaporation occurs from the pile surface at a decreasing rate for several days after rainfall and continuously from the pile surface adjacent to the springs. Although the evaporation phenomenon was recognized as a variable, it was not related to the overall hydrologic balance. An assumption was made, based on the physical characteristics observed on the pile, that the concentration of acid products in the direct runoff was similar to the concentration in the water infiltrating into the pile. The difference in concentrations observed in the base flows was attributed to evaporation losses rather than to any further significant oxidation within the pile.

Ground Water Survey

To identify the nature of the water seepage at the base of the refuse pile (hereafter referred to as base flows), the original plan called for monitoring these flows, both quantity and quality, on a predetermined schedule. Since observed flows were very small or intermittent, the bucket-stopwatch technique was used to measure these flows. As a further aid toward understanding these base flows from within the pile, fourteen observation wells were drilled to the original ground level below the pile and each cased with 1-inch diameter PVC plastic pipe, Figure 7. Water level measurements of the pile storage pool were determined regularly by lowering an electrical probe down the tube.

Simulated Rainfall Test Plots

To allow the collection of supplementary acid formation data under closely controlled conditions and to guard against the possibility of a sustained drought during the data collection period, a small (0.109 acre) simulated rainfall test plot was installed on a representative section of the refuse pile. Figure 8 shows the plot, sprinkler system, collection ditches, and pump system. Uncontaminated water from a nearby ground water source was applied via irrigation sprinklers at desired metered rates. The direct runoff was collected in the ditching system and measured by a flume at the outlet. Throughout the simulation runs, water quality samples were manually collected. Acid formation rates from this test plot, together with those obtained during periods of natural precipitation, were used in estimating the average acid formation rate from the refuse pile.

Hypothesis of Acid Formation

The following fundamental hypothesis was used to allow the calculation of an average acid formation rate for the refuse pile:

1. The oxidation of pyrite is primarily confined to a relatively narrow zone at or near the surface of the pile with the products of the reaction accumulating in this zone to be flushed out during periods of precipitation and appearing in the runoff, and

2. The acid load from the refuse pile is directly proportional to the acid load from the surface runoff and inversely proportional to the ratio of total storm runoff to the total rainfall, seepage at the base of the pile being disregarded.

This hypothesis can then be expressed mathematically using the following relationship:

$$P = \frac{\Sigma R}{A \times \Sigma t \times f}$$

where

P = Average acid formation rate, lb/acre/day
ΣR = Total weight of acidity in runoff from all storms on record for a given drainage area, in lb acidity as $CaCO_3$
A = Surface drainage area in acres
Σt = Total period of acid formation corresponding to all storms on record, in days
f = Ratio of total storm runoff volume to total rainfall volume for all storms on record

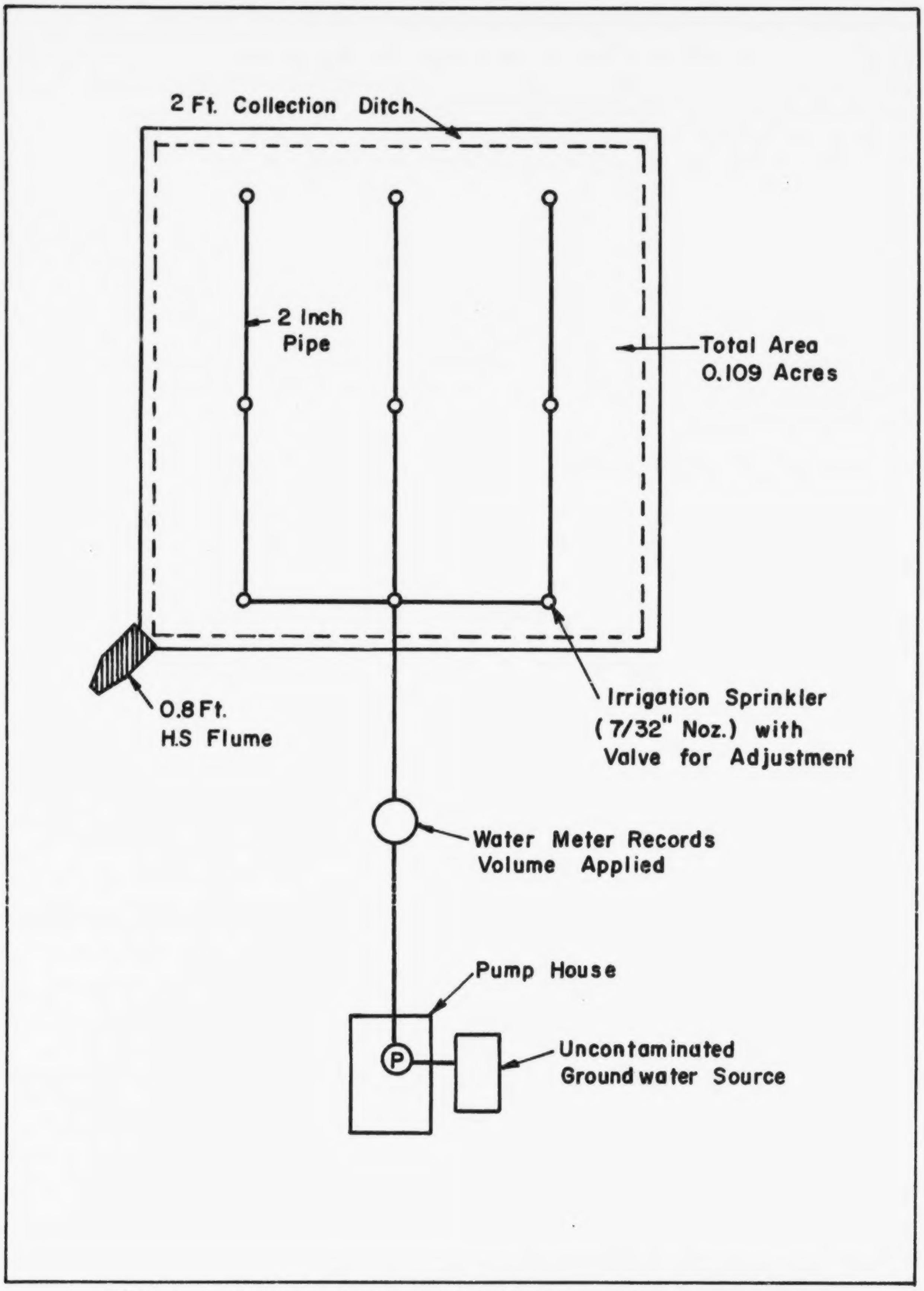
2 Ft. Collection Ditch
2 Inch Pipe
Total Area 0.109 Acres
0.8 Ft. H.S Flume
Irrigation Sprinkler (7/32" Noz.) with Valve for Adjustment
Water Meter Records Volume Applied
Pump House
P
Uncontaminated Groundwater Source

FIG. 8 SIMULATED RAINFALL TEST PLOT

A detailed example of the methodology used in developing the storm data from which acid formation rates were subsequently estimated follows. The storm of July 24, 1969, monitored at Area 6, was selected for this example.

At the first sign of the storm, manpower with sample bottles was deployed to the Area 6 monitoring station. When the rain began to fall, samples of the runoff were taken at the flume at approximately 2-minute intervals and at longer intervals as the storm subsided. At the completion of the storm, samples were returned to the laboratory and analyzed for acidity and other items. The following day, charts were removed from the stage recorder and rain gage, necessary notations completed, and these data, together with the analytical data obtained from samples taken during the storm were correlated.

Using the flow data and acid analyses, instantaneous mass flows of acid were calculated. As an example, at 1626 hours, the flow at the flume was determined from the stage recorder to be 0.934 CFS. The acidity of the sample taken at the corresponding time was 14,750 mg/l acidity. The instantaneous mass flow of acid was calculated as:

$$\frac{0.934\ \text{ft}^3}{\text{sec}} \times \frac{60\ \text{sec}}{\text{min}} \times \frac{1440\ \text{min}}{\text{day}} \times \frac{62.4\ \text{lb}}{\text{ft}^3} \times 0.01475$$

$$= 74{,}500\ \text{lb/day acid}$$

A composite of the data for the storm of July 24, 1969 is presented in Table II.

TABLE II. HYDROGRAPH DATA
JULY 24, 1969 - AREA 6

I Time of Day	II Flow CFS	III Acidity mg/l	IV Acid lb/Day	V Time Since Storm Started (min)
1618	1st Flow	37,600	-	0
1622	0.00153	No Sample	-	4
1624	0.099	18,900	10,100	6
1626	0.934	14,750	74,500	8
1628	2.30	11,750	146,000	10
1631	2.02	7,925	86,500	13
1633	1.31	7,575	53,500	15
1639	0.715	No Sample	-	21
1657	0.605	7,100	23,200	39
1705	0.099	No Sample	-	47
1710	0.0278	9.075	1,360	52
1730	0.0007	11,730	44	72

The flow in CFS (Column II) was then plotted against time, in minutes, since the storm started (Column V) and the points connected with a smooth curve, Figure 9A, Runoff Volume. The area under the curve was planimetered to obtain the total runoff, 2834 ft^3, measured at the flume during the monitored period.

Next, the instantaneous mass flow of acid, in lb/day (Column IV), was plotted against time, in minutes, since the storm started (Column V) and the points connected with a smooth curve, Figure 9B, Acid Load. The area under the curve was then planimetered to obtain 1,111 lb acid, the total acid load measured at the flume during the monitored period.

The rainfall, as determined from the rain gage chart during this monitored storm, was 0.39 inches. The watershed associated with Area 6 was measured as 2.71 acres. Rainfall on Area 6 watershed during the monitored storm was therefore:

$$0.39 \text{ in.} \times 2.71 \text{ A} \times \frac{43,560 \text{ ft}^2}{\text{A}} \times \frac{1 \text{ ft}}{12 \text{ in.}} = 3837 \text{ ft}^3$$

The elapsed time from the previous storm was determined to be 2.2 days, from the rain gage charts.

Typical hydrographs from the simulated rainfall test plot, Area 1 and Area 2, are shown in Figures 10, 11, and 12, respectively. Data from the simulated rainfall test plot were treated in a similar manner except that a water meter was used to measure the amount of "rainfall", i.e., water applied to the test plot.

A summation technique was then used in estimating an average acid formation rate for the specific area. The area acid formation rates were then averaged, weighted in accordance to the areas represented by the test data, to obtain an average acid formation rate for the entire refuse pile.

Results and Discussion

The acid formation rates, in pounds of acidity, as $caCO_3$, per acre per day (lb/A/day) from the simulated rainfall test plot and from Areas 1, 2, and 6 are shown in Tables III, IV, V, and VI for the individual tests or storms monitored. These results are summarized in Table VII.

Because of topographic similarities of Areas 1 and 2, the acid formation rates were averaged for these two areas, weighted in accordance with the number of storms monitored, to produce a single value representative of the steep slope

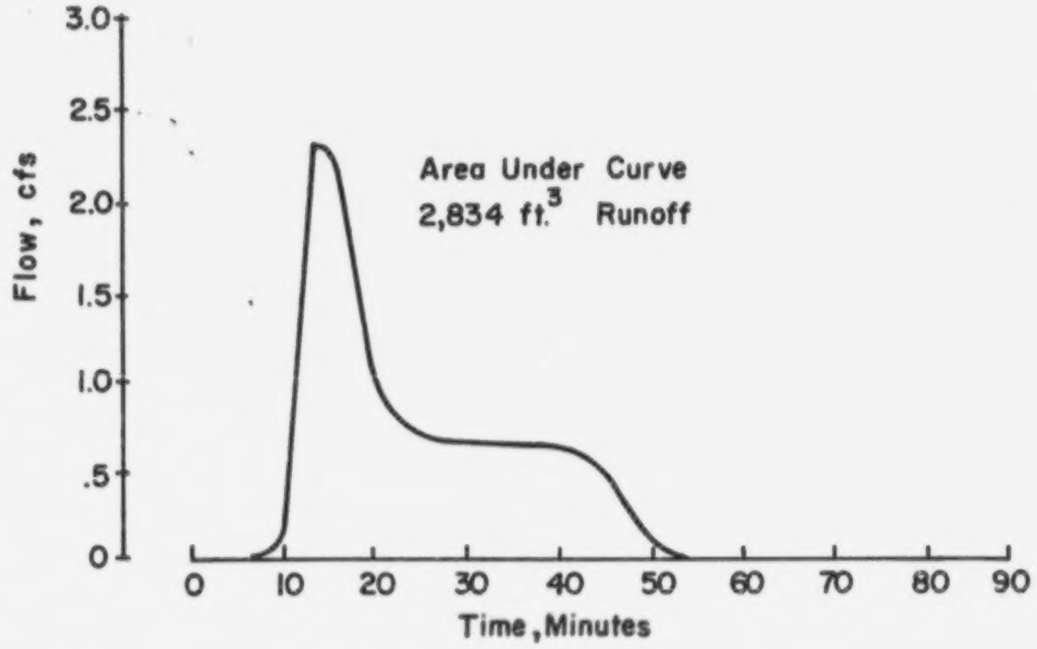

FIG. 9A RUNOFF VOLUME

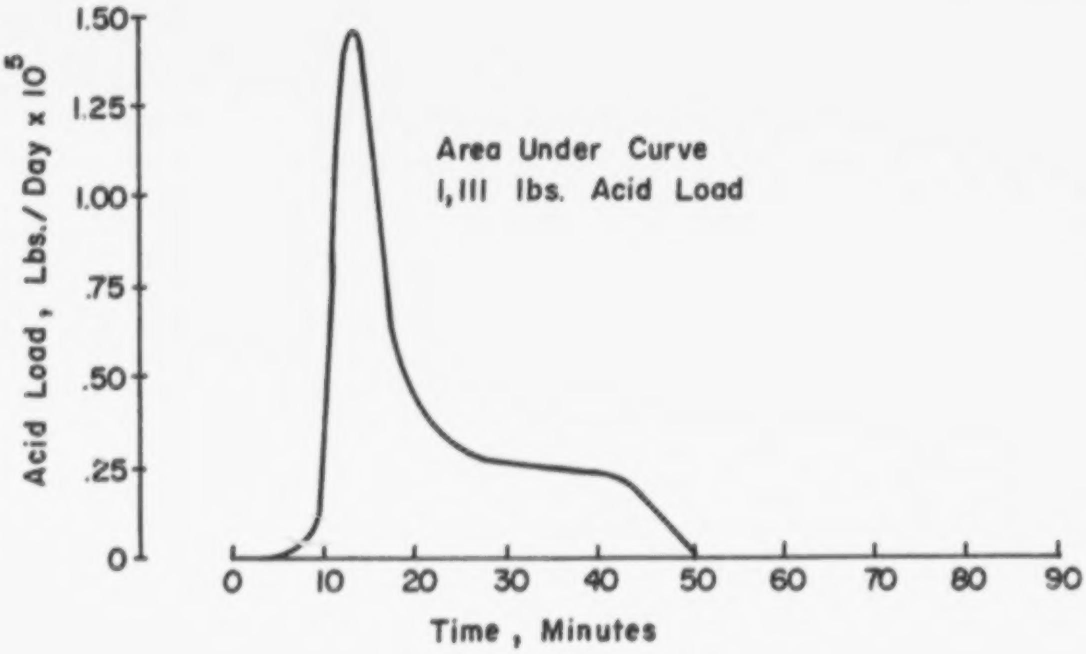

FIG. 9B ACID LOAD

FIG. 9 HYDROGRAPHS, STORM JULY 24, 1969, AREA 6

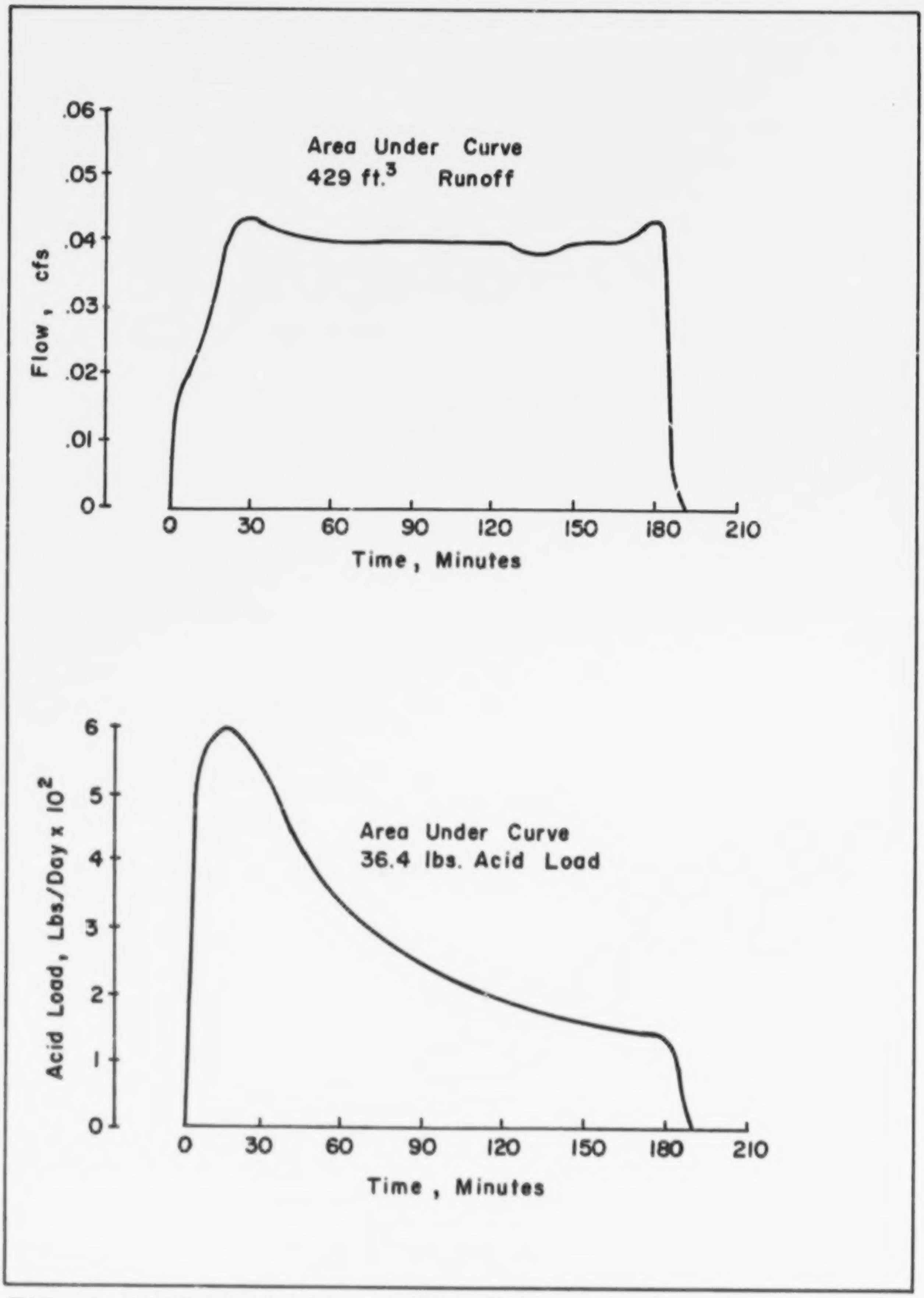

FIG. 10 HYDROGRAPHS, SEPTEMBER 2, 1969, TEST PLOT

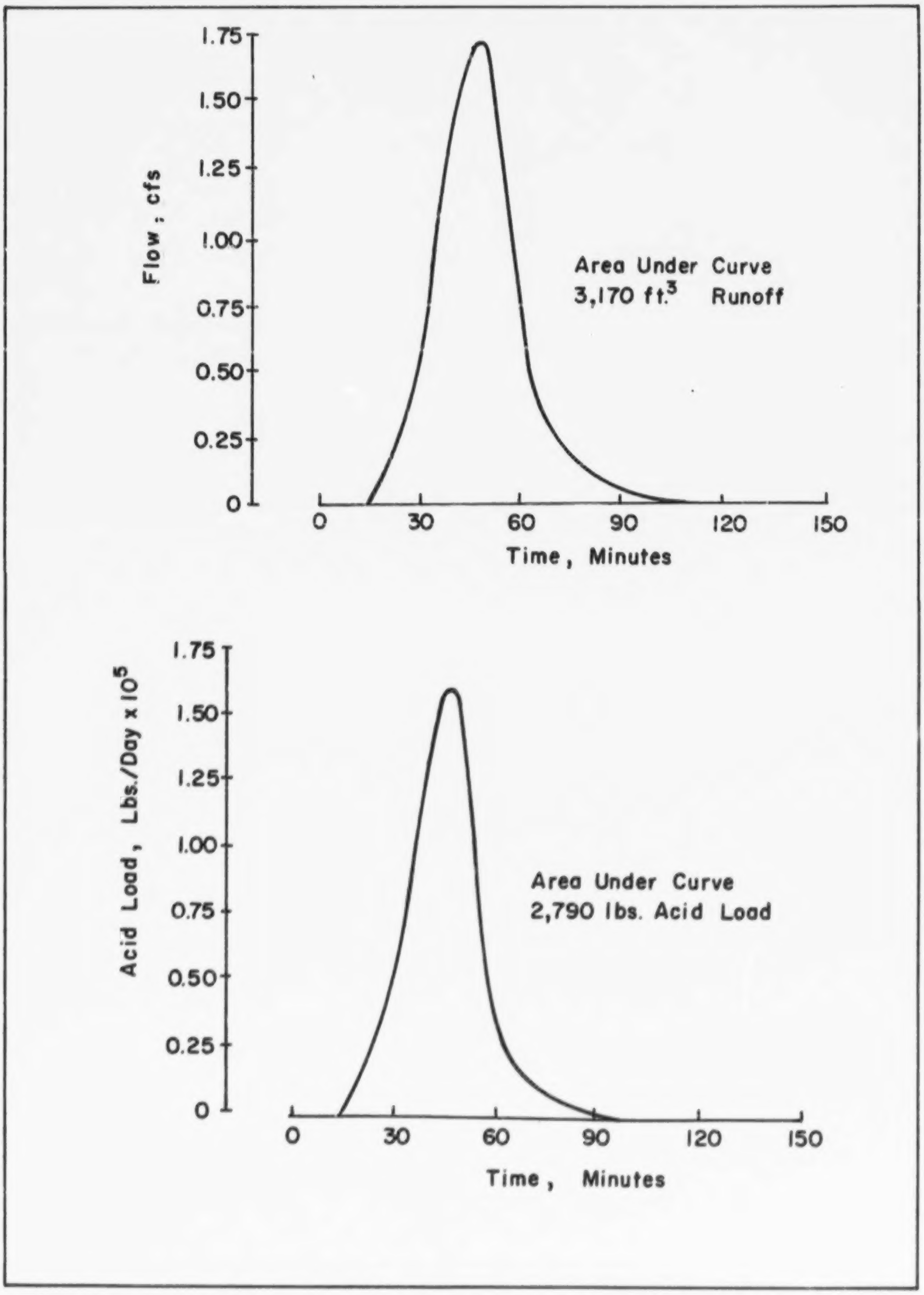

FIG. 11 HYDROGRAPHS, STORM AUGUST 20, 1969, AREA 1

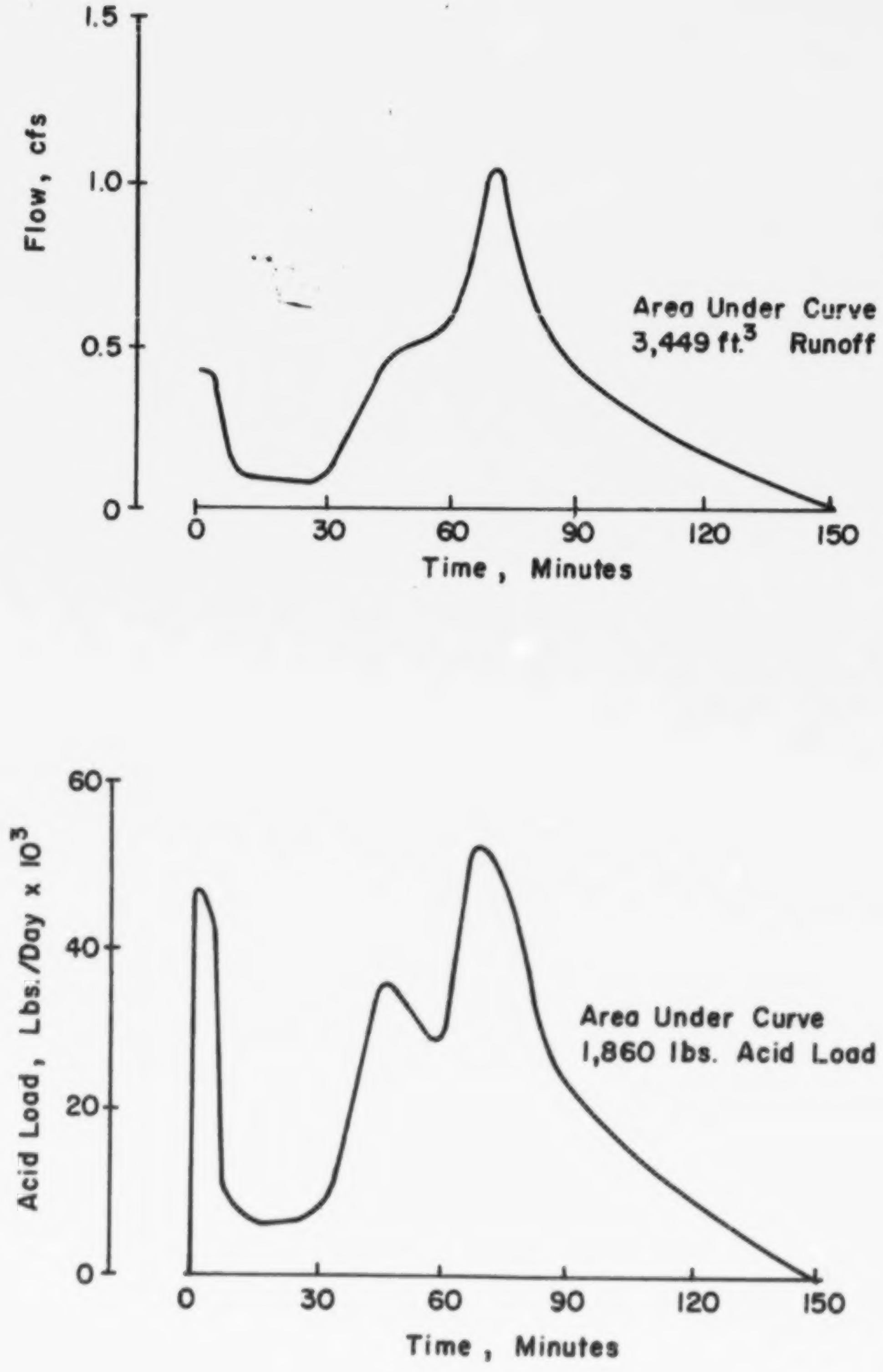

FIG. 12 HYDROGRAPHS, STORM SEPTEMBER 16, 1969, AREA 2

TABLE III. ACID FORMATION RATE - SRTP*

Date	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lbs
8/1/69	1,093	659	4.3	30.7
8/5/69	1,186	703	4.0	56.3
8/11/69	519	231	6.2	16.6
8/12/69	689	455	0.7	22.4
8/22/69	584	385	1.6	20.2
8/26/69	967	561	3.9	36.6
8/29/69	686	414	2.8	32.2
9/2/69	719	429	3.9	36.4
9/5/69	1,621	1,237	1.2	31.4
9/6/69	405	235	0.9	7.4
9/9/69	710	445	2.3	18.7
9/30/69	1,592	1,159	13.7	61.9
10/7/69	790	663	0.5	21.7
Σ13	Σ11,561	Σ7,576	Σ46.0	Σ392.5

Area of Simulated Rainfall Test Plot = 0.109 A
f = 7576 ÷ 11,561 = 0.655

$$\text{Acid Formation Rate} = \frac{392.5 \text{ lbs}}{0.109 \text{ A} \times 46.0 \text{ days} \times 0.655}$$

$$= 120 \text{ lbs/A/day}$$

---

*Simulated Rainfall Test Plot

TABLE IV. ACID FORMATION RATE - AREA 1

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lbs
8/20/69	0.35	15,627	3,170	2.5	2,790
3/17/70	0.55	24,557	3,270	13	1,123
4/12/70	0.74	33,040	9,480	10	3,010
5/25/70	0.20	8,930	441	10	300
5/29/70	0.40	17,860	3,090	4	230
Σ5		Σ100,014	Σ19,451	Σ39.5	Σ7,453

Area 1 = 12.30 A
f = 19,451 ÷ 100,014 = 0.194

$$\text{Acid Formation Rate} = \frac{7{,}453 \text{ lbs}}{12.30 \text{ A} \times 39.5 \text{ days} \times 0.194}$$

$$= 79 \text{ lbs/A/day}$$

area typical of the periphery of the refuse pile, thus

Area 1 79 x 5 storms = 395
Area 2 193 x 22 storms = 4246
Σ27 Σ4641

Average for Area 1 and 2 = 172 lb/A/day

Using the contour map of the refuse pile and visual inspection, the refuse pile was divided into areas considered representative of the test data. This procedure resulted in estimating approximately 13 acres of compacted refuse area typical of the area on which the simulated rainfall tests were conducted. The steep slope areas were estimated to consist of approximately 14 acres represented by the results from Area 1 and 2. The uncompacted dumped refuse area was approximately 13 acres represented by the results from Area 6. Applying the acid formation rates to these respective areas, an average acid formation rate for the pile was calculated:

Compacted Refuse (SRTP) 13 acres x 120 = 1560
Steep Slope Area (Area 1 and 2) 14 acres x 172 = 2408
Uncompacted Refuse (Area 6) 13 acres x 305 = 3965
Σ40 Σ7933

Average = 198 lb/A/day

TABLE V. ACID FORMATION RATE - AREA 2

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lbs
7/21/69	1.20	17,206	6,270	7	2,290
9/16/69	0.75	10,754	3,449	8.4	1,860
3/17/69	0.55	7,886	160	13	119
3/21/70	0.20	2,868	337	4	404
3/25/70	0.40	5,735	545	1.7	456
3/25/70	0.40	5,735	1,761	0.3	815
4/2/70	0.40	5,735	335	8	313
4/12/70	0.74	10,610	3,269	10	1,851
4/28/70	0.50	7,169	1,717	1	353
5/10/70	1.38	19,787	1,710	10	1,371
5/11/70	0.88	12,618	3,590	1	500
5/15/70	0.45	6,452	858	4	298
5/29/70	0.40	5,735	164	4	102
5/30/70	0.20	2,868	1,500	1	350
5/31/70	0.25	3,585	2,040	1	622
6/1/70	0.75	10,754	3,210	0.3	900
6/1/70	0.15	2,151	294	0.4	164
6/1/70	0.35	5,018	1,930	0.3	745
6/2/70	0.53	7,599	798	1	454
6/3/70	1.33	19,070	5,460	1	740
6/4/70	0.25	3,585	611	1	312
6/13/70	0.35	5,018	982	9	331
Σ22		Σ177,936	Σ40,990	Σ87.4	Σ15,350

Area 2 = 3.95 A
f = 40,990 ÷ 177,936 = 0.230

$$\text{Acid Formation Rate} = \frac{15{,}350 \text{ lbs}}{3.95 \text{ A} \times 87.4 \text{ days} \times 0.230}$$

$$= 193 \text{ lbs/A/day}$$

TABLE VI. ACID FORMATION RATE - AREA 6

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lbs
7/24/69	0.39	3,837	2,834	2.2	1,111
8/20/69	0.35	3,443	1,537	2.5	1,530
9/16/69	0.75	7,378	4,479	8.4	2,330
2/7/70	0.25	2,459	329	8.5	250
2/7/70	0.45	4,427	1,732	0.5	796
1/17/70	Snow Melt		990	10	280
2/20/70	0.45	4,427	344	5	278
3/1/70	0.20	1,967	784	7	750
3/2/70	1.30	12,788	8.239	1	17,827
3/3/70	0.14	1,377	260	1	185
3/4/70	0.45	4,427	454	1	374
3/17/70	0.55	5,411	1,128	13	681
3/25/70	0.95	9,345	2,830	1	17,300
4/12/70	0.74	7,280	5,750	10	1,900
4/23/70	0.23	2,263	274	5	144
4/27/70	0.60	5,902	4,463	5	817
4/30/70	0.55	5.411	1,450	2	47
5/10/70	1.38	13,575	10,400	10	1,450
5/11/70	0.88	8,657	8,300	1	2,890
5/15/70	0.60	5,902	769	4	142
5/25/70	0.20	1,967	255	10	198
5/29/70	0.60	5,902	4,900	4	3,850
6/1/70	0.90	8,854	5,799	0.5	1,496
6/1/70	0.35	3,443	2,820	0.5	604
6/2/70	0.53	5,214	2,840	;	478
6/3/70	1.33	13,084	7,240	1	1,372
6/13/70	0.35	3,443	2,410	9	718
6/19/70	0.10	984	155	6	171
6/24/70	0.20	1,967	312	4	195
Σ29		Σ155,134	Σ84,077	Σ134.1	Σ60,164

Area 6 = 2.71 A
f = 84,077 ÷ 155,134 = 0.542

$$\text{Acid Formation Rate} = \frac{60{,}164 \text{ lbs}}{2.71 \text{ A} \times 134.1 \text{ days} \times 0.542}$$

$$= 305 \text{ lbs/A/day}$$

TABLE VII. SUMMARY OF ACID FORMATION RATES

Area	Acid Formation Rate lbs/A/day	Number of Tests or Storms Monitored
SRTP	120	13
Area 1	79	5
Area 2	193	22
Area 6	305	29

Thus the average rate of acid formation for this particular refuse pile was 198 pounds of acidity, as $CaCO_3$, per acre per day.

Two points should be mentioned regarding the results obtained by this method. The first relates to the temperature effects on acid formation. The data are not considered sufficiently accurate to reflect temperature effects and thus the acid formation rates reported herein can only be considered as average values. Although a continuous record of temperatures was obtained near the Area 6 flume at ambient level, 3 inches below the surface, and 18 inches below the surface, the temperature effects were not related to the average acid formation rate. It is believed that due to the dark surface of the pile, sunlight warms the surface mantle rapidly and acid production probably continues during all but the coldest months of the winter at this location. Temperature data are reported in Appendix XI-C.

The second relates to the fact that seepage flows are tributary to the ponds above the flumes of Area 1 and 2. Due to the rapid flush of water during a storm, it would appear that seepage water accumulated in the ponds from a previous storm has little effect on the acid weight determined from the runoff data. Due to the lack of sufficient data, however, this point cannot be checked with any precision.

The data obtained from the ground water survey were inconclusive. Although considerable effort was expended in monitoring the water levels in the observation wells and obtaining base flow and quality data, these data were not amenable to any analysis and no rational correlations were evident. All wells, with the exception of #1, 13, and 15, indicated water level variations of 1 foot or more with well #2 showing a 33.02 foot maximum variation. Comparison of the overall situation with regard to the locations of the more variable wells with the observed points of seepage flow did not yield a positive correlation between base flows and well elevation. While the well data indicate the location of some of the storage pool water movement in the pile, a Theissen polygon network analysis of the observation well data did not yield any significant volume figures. The storage pool in the pile appeared to be comprised of several unique pools of water, interconnected, that feed the individual base flow points. It appears that a more closely spaced network of wells would be required to give an adequate picture of ground water storage and movement. The data are included in Appendix XI-E and Appendix XI-G.

A number of samples were taken from Walker Creek, upstream and downstream from the site and at a point three miles downstream from the site, at Route 127. These data are included in Appendix XI-D and are to be used as reference points during the monitoring program of Phase II.

As mentioned earlier, severe corrosion problems were experienced with the non-stainless steel flumes and drop boxes used to measure the surface runoff. As an alternative material of construction, kiln-dried, untreated lumber or marine-type plywood could be used. The wood should be essentially free of knots and cracks and adequately reinforced. Waterproof glue and stainless steel bolts are recommended for fasteners. Weir plates should be made of stainless steel, Type 304 or Type 316, and regularly inspected and replaced at the first sign of deterioration. A variety of other materials such as reinforced plastics, coated steels, concrete, and cements should also be considered for flume construction. However, each of these materials has certain practical limitations and a careful evaluation of each should be made before final selection.

Supplementary Experiments

The following supplementary experiments were conducted during the course of this study and are briefly summarized herein:

1) Role of Bacteria in Acid Formation

   A study was conducted to determine what role, if any, bacterial catalysis may play in the oxidation of pyrite. The initial conclusions, reported by Lau[3] et al, indicated sound evidence for the occurrence of significant catalysis of pyrite oxidation only in environments such as are found at the surface of refuse piles and spoil banks. Bacterial catalysis is less likely in underground environments.

2) Application of Bactericides

During the bacterial catalysis studies, a number of bactericides were applied to the simulated rainfall test plot on the refuse pile to determine if the oxidation of pyrite could be reduced or arrested. Hexionic acid, sodium lauryl sulfate, and linear alkyl benzene sulfonate were applied separately.. No significant reduction in the acid formation rate was noted.

3) Laboratory Acid Formation Rate Studies

In an effort to substantiate the acid formation rate estimated in the field studies, refuse samples were tested in the laboratory for oxygen uptake at 25°C in a Warburg apparatus. An average of nine tests on the random samples taken from the pile mantle indicated an acid formation rate of 107 lbs/A/day.

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EXPERIMENTAL ABATEMENT MEASURES

Rationale for Abatement

One of the objectives of this project was to demonstrate water and air pollution abatement measures which would be essentially permanent, require little need for continued maintenance, and would present a pleasing aesthetic appearance. The basic approaches discussed were ways to minimize the movement of air and/or water into the pile by sealing the pile with a suitable cover (organic, mechanical, or chemical), thus reducing or eliminating completely the formation of acid, siltation, erosion, and dust entrainment.

A cover should function to varying degrees in one or more of the following ways:

1. The cover may prevent erosion and thus prevent the continuing exposure of fresh pyrite surfaces. Since oxygen must be continuously supplied to support the pyrite oxidation reaction and since any layer of material separating pyrite from the atmosphere will function as a resistance to diffusion, then any physical stabilization of the pile surface will cause the zone of oxidation to move deeper into the pile and the overlying diffusion barrier will eventually control the rate of pyrite oxidation. The reaction will decrease with time due to this effect, although the decrease may be very slow.

2. The cover may be sufficiently impermeable to oxygen transport to act as an efficient diffusion barrier. For example, a plastic sheet placed over the refuse may effectively stop all oxygen transport to the pyrite and oxidation will cease.

3. The cover may be sufficiently impermeable to water movement to decrease or stop water movement into the refuse. If this occurs, then oxidation products will not be flushed away from the oxidation sites and the only movement of acid salts into the interior of the pile will be through seepage generated by the hygroscopic nature of the acid salts themselves. Depending on oxygen availability, pyrite oxidation may continue, but the products will be largely retained at or near the site of oxidation.

4. The cover may function as an oxygen-consuming layer. A vegetative cover such as grass might build up a sufficiently high concentration of organic matter in the soil

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to support high rates of aerobic bacterial activity. Such a layer might be effective in removing oxygen from the soil atmosphere before it reaches the zone of pyrite oxidation.

Attention was directed largely toward vegetative covers that could be applied using standard agricultural techniques without resorting to new and untried equipment and/or machinery. Such covers would be self-healing and would prevent further exposure of pyrite by erosion. A selection of grasses and legumes were considered to be the best approach in this experimental program.

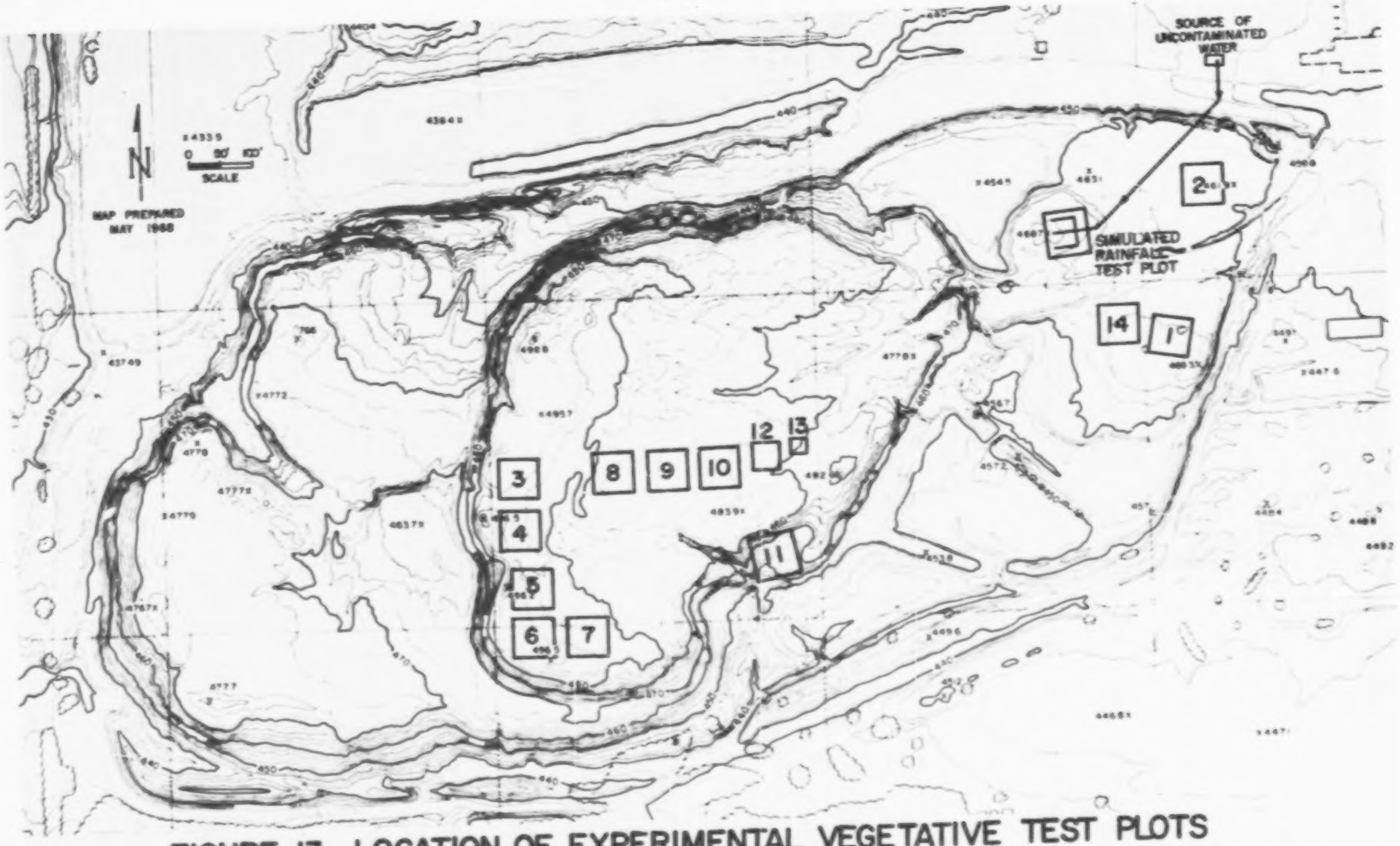
Accordingly, fourteen 0.1 acre test plots were established on the refuse pile outside the limits of drainage Areas 1, 2, and 6. The location of these plots is shown in Figure 13. In addition, three test plots were established on the slurry lagoons.

Plots 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, and 14 were equipped with a tile underdrain laid one to two feet below the surface of the gob and the boundaries of the plots were ditched to prevent the flow of surface acid runoff from adjacent areas across the plots. Monitoring of the plots consisted of visual observation of the growth of grasses, chemical analysis of soil samples taken from the refuse layer at the interface of the refuse with the various applied covers, and chemical analysis of subsurface drainage caught in the underdrain.

The grass species selected were recommended by the USDA Soil Conservation Service based on their experience at this locale. In establishing grass covers on test plots using a topsoil cover, samples of soil were submitted to a soil testing laboratory, Agrico Chemical Division, Continental Oil Company, to determine limestone and fertilizer requirements (Appendix XI-J). In the case of test plots planted directly on refuse or on slurry lagoon material without the use of topsoil, a modified soil test was developed and used as a guide after it became apparent that the standard soil test was not applicable to these types of material.

The treatment procedures used in establishing the experimental covers were as follows and are summarized in Table VIII.

Plot 1 Established June, 1969. Agricultural limestone, 48 x 100 mesh, applied at 40 T/A, rototilled into the refuse to a depth of 8". Commercial fertilizer, 6-24-24, applied at 1500 lb/A. Seeded with a mixture of Kentucky fescue (37½% by weight) and perennial rye (62½%) at 80 lb/A. Straw mulch spread on surface at 1½ T/A.


SOURCE OF UNCONTAMINATED WATER
SIMULATED RAINFALL TEST PLOT
MAP PREPARED MAY 1968
N
0 50' 100'
SCALE
1
2
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14

FIGURE 13 LOCATION OF EXPERIMENTAL VEGETATIVE TEST PLOTS

TABLE VIII. EXPERIMENTAL VEGETATIVE TEST PLOTS

Test Plot No.	Location	Date Installed	Barrier	pH Adjustment		Fertilizer		Grass Seed	
				Type	Rate T/A	Type	Rate Lb/A	Type	Rate Lb/A
1	Refuse pile	June 1969	None	Limestone(1)	40	6-24-24	1500	Ky. fescue Per. rye mix	30 50
2	Refuse pile	July 1969	None	Limestone	40	6-24-24	1500	Ky. fescue Per. rye mix	30 50
3	Refuse pile	Sept. 1969	None	Limestone	40	6-24-24	1500	Ky. fescue Per. rye mix	30 50
4	Refuse pile	Sept. 1969	None	Limestone	40	6-24-24	1500	Ky. fescue Per. rye mix	30 50
5	Refuse pile	Sept. 1969	None	Limestone	40	6-24-24	1500	Ky. fescue Orchard mix	30 50
6	Refuse pile	Oct. 1969	Polyethylene membrane plus 4" topsoil	Limestone	2	6-24-24	1000	Ky. fescue	50
7	Refuse pile	Control plot	None	None		None		None	
8	Refuse pile	Oct. 1969	4" topsoil	Limestone	2	6-24-24	500	Ky. fescue Orchard mix	40 30
9	Refuse pile	Oct. 1969	12" topsoil	Limestone	2	6-24-24	500	Ky. fescue ½ Orchard ½	40 40
10	Refuse pile	Oct. 1969	24" topsoil	Limestone	2	6-24-24	500	Ky. fescue ½ Orchard ½ Lespedeza both sides	40 40 10
11	Refuse pile	Oct. 1969	None	Limestone	40	6-24-24	1500	Ky. fescue Per. rye mix	30 50
12	Refuse pile	Oct. 1969	4" dried sewage sludge	None		None		Ky. fescue Per. rye mix	10 10
13	Refuse pile	Oct. 1969	Lime sludge from oil refinery water treatment plant	None		None		None	
14	Refuse pile	Nov. 1969	Waste lime-limestone mixture	Code L	90	None		None	
15	Slurry lagoon	June 1970	3" topsoil tilled into slurry to form wind rows	Limestone	2	6-24-24	500	Grass seed mix	65
16	Slurry lagoon	May 1970	None	Limestone	15	45-0-0 0-46-0 0-0-60	200 300 300	Oats Ky. fescue Sudan grass mix	40 20 30
17	Slurry lagoon	May 1970	Coherex	None		None		None	

(1) Agricultural limestone used on Test Plots was 48 x 100 mesh

Note: All test plots planted to grass were covered with straw mulch at 1½ T/A.

Plot 2	Established July, 1969. Agricultural limestone, 48 x 100 mesh, applied at 40 T/A, rototilled into the refuse simultaneously with 1 T/A straw to a depth of 8". Commercial fertilizer, 6-24-24, applied at 1500 lb/A. Seeded with a mixture of Kentucky fescue (37½%) and perennial rye (62½%) at 80 lb/A. Straw mulch spread on surface at 1½ T/A.
Plot 3	Established September, 1969. Agricultural limestone 48 x 100 mesh, applied at 40 T/A disked into refuse to a depth of 8". Commercial fertilizer, 6-24-24, applied at 1500 lb/A. Seeded with a mixture of Kentucky fescue (37½%) and perennial rye (62½%) at 80 lb/A. Straw mulch spread on surface at 1½ T/A.
Plot 4	Duplicate of Plot 3 with identical results.
Plot 5	Established September, 1969. Agricultural limestone 48 x 100 mesh, applied at 40 T/A, disked into refuse to a depth of 8". Commercial fertilizer, 6-24-24, applied at 1500 lb/A. Seeded with a mixture of Kentucky fescue (37½%) and orchard grass (62½%) at 80 lb/A. Straw mulch spread on surface at 1½ T/A.
Plot 6	Established October, 1969. Black polyethylene membrane, 39 mils thick, was placed on the graded refuse. A 4" thickness of field soil was placed on the membrane. Set out for percolation tests initially. In March, 1970, agricultural limestone, 48 x 100 mesh, applied at 2 T/A, was raked into the soil. Commercial fertilizer, 6-24-24, applied at 1000 lb/A. Seeded with Kentucky fescue at 50 lb/A. Straw mulch spread on surface at 1½ T/A.
Plot 7	Control plot; no treatment.
Plot 8	Established October, 1969. A 4" thickness of field soil placed on the refuse. Agricultural limestone, 48 x 100 mesh, at 2 T/A, was hand-raked into the soil. Commercial fertilizer, 6-24-24, applied at 500 lb/A. Seeded with a mixture of Kentucky fescue (57%) and orchard grass (43%) at 70 lb/A. Straw mulch spread on surface at 1½ T/A.
Plot 9	Established October, 1969. A 12" thickness of field soil was placed on the graded refuse. Agricultural limestone, 48 x 100 mesh, at 2 T/A, hand-raked into the soil. Commercial fertilizer, 6-24-24, applied at 500 lb/A. One-half of test plot seeded with

Kentucky fescue at 40 lb/A and one-half of plot seeded with orchard grass at 40 lb/A. Straw mulch spread on surface at 1½ T/A.

Plot 10 Established October, 1969. A 24" thickness of field soil was placed on the graded refuse. Agricultural limestone, 48 x 100 mesh, at 2 T/A, hand-raked into the soil. Commercial fertilizer, 6-24-24, applied at 500 lb/A. One-half of test plot seeded with mixture of Kentucky fescue (80%) and lespedeza (20%) at 50 lb/A. The other half of test plot seeded with mixture of orchard grass (80%) and lespedeza (20%) at 50 lb/A. Straw mulch spread on surface at 1½ T/A.

Plot 11 Established in October, 1969 on a 4:1 slope with southern exposure. Agricultural limestone, 48 x 100 mesh, applied at 40 T/A, disked into refuse. Commercial fertilizer, 6-24-24, applied at 1500 lb/A. Seeded with a mixture of Kentucky fescue (37½%) and perennial rye (62½%) at 80 lb/A. Straw mulch spread on surface at 1½ T/A.

Plot 12 Established October, 1969. Dried sewage sludge at 4" thickness was applied to the surface of the refuse. Seeded with a mixture of Kentucky fescue (50%) and perennial rye (50%) at 20 lb/A.

Plot 13 Established October, 1969. Lime Sludge from an oil refinery water treatment plant at 95 T/A was spread on the surface. The material was slightly oily and was not mixed into the refuse. Test plot set out for percolation tests only.

Plot 14 Established November, 1969. A finely ground mixture of lime and limestone, labeled Code L from Mississippi Lime Company, applied at 90 T/A, was disked into refuse to a depth of 6". Test plot was set out for percolation tests only.

Three additional test plots were established during this investigation on the slurry lagoons and are summarized as follows:

Plot 15 Established June, 1969. A series of 24 strips, 200 ft long, 3 ft wide, and on 9 ft centers were staked out on the slurry lagoons. Field soil at 3" thickness was applied to the strips and rototilled to a depth of 3". Agricultural limestone, 48 x 100 mesh, at 2 T/A, was hand-raked into the surface. Commercial fertilizer, 6-24-24, at 500 lb/A was applied.

The strips were seeded with a mixture of Kentucky fescue (31%), lespedeza (15%), red clover (8%), and perennial rye (46%) at 65 lb/A. Straw mulch at 1½ T/A was spread on the surface.

Plot 16 Established May, 1970. Agricultural limestone, 48 x 100 mesh, was rototilled into a 0.1 acre test plot of slurry lagoon material to a depth of 8", at 15 T/A. Urea, 45-0-0, at 200 lb/A, triple-super phosphate, 0-46-0, at 300 lb/A, and potash, 0-0-60, at 300 lb/A were applied. The test plot was seeded with a mixture of Kentucky rescue (22%), sudan grass (34%), and oats (44%) at 90 lb/A. Straw mulch at 1½ T/A was spread on the surface. This test plot was completed on an extremely windy day and the mulch was held down with binder twine anchored to stakes to prevent the seed from blowing away.

Plot 17 Established May, 1970. A 10 ft by 10 ft test plot was established to determine the stabilizing effect of a petroleum-based product, "Coherex".* The use of Coherex as a stabilizing agent for mineral wastes has been reported by the Bureau of Mines.[4] A one-gallon sample of Coherex was mixed with 6 gallons of water and the mixture was applied at a rate of one gallon per square yard to the slurry lagoon test plot using a garden sprinkler can.

Results and Discussion

In summary, grass was established on all test plots planted to grass on the refuse pile, with and without the use of topsoil. The grass plots weathered well through one winter season and continued growth was visible during the second season. The control plot, No. 7, remained barren during this entire period.

Grass covers established on Plots 1 and 2 produced excellent stands of grass. Figure 14 shows the grass cover on Plot 2 established directly in the refuse without the addition of any topsoil. As visually observed, the vegetative covers on Plots 1 and 2 were significantly more uniform, with denser grass than the grass covers on Plots 3, 4, and 5.

This improvement is attributed to the use of rototilling equipment when applying the limestone on the former plots as contrasted to discs used on the latter. A more intimate mixing of limestone with refuse material is believed to have taken place. Average pH values of the "soil" on Plots 1 and 2 were pH 4.7 and pH 4.9 respectively for the first six months of 1970. No data were collected for Plots 3, 4, and 5 because of the spotty condition of the vegetation.

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*Golden Bear Oil Company, Bakersfield, California

Plot 6, using a polyethylene membrane and a 4-inch thickness of topsoil, presented several problems. Spreading of plastic was a very difficult task even during a calm day. Soil was piled on one edge and then spread ahead by a small bulldozer. Great care was taken to protect the plastic but it was difficult to be certain that it was not punctured in the process of spreading the soil. This plot was initially set out without grass cover for percolation tests only. Grass was planted on this plot in Spring 1970 and a good cover of grass was established.

Plot 7, control plot, remained barren during the entire test period. One sample of the refuse material taken in June, 1970 showed a pH 2.3.

Plot 8, established with a 4-inch thickness of topsoil, had good grass growth where the soil thickness was maintained. However, the plot was relatively small to be worked with even the smallest farm equipment and refuse was exposed, resulting in a spotty grass cover. This problem was not experienced to the same degree in Plots 9 and 10 that were covered with 12 inches and 24 inches of topsoil.

Plot 9 wintered well into the 1970 growing season. The fescue did better than the orchard grass.

Plot 10 showed good grass growth on both sides in the Spring 1970. The legumes (lespedeza) appeared in June 1970.

Plot 11 produced a spotty grass cover, apparently due to poor mixing of limestone with the refuse. A disc attachment was used on a small farm tractor. Results were similar to Plots 3, 4, and 5.

Plot 12, established with dried sewage sludge in October 1969, produced no vegetation until Spring 1970, when a heavy growth of grass appeared including tomato plants and a number of weed species.

Plots 13 and 14 were set out for percolation tests only.

The wind rows of grass established on the slurry lagoons grew well in 1969 and even better in 1970. Visual observation of the areas between the rows in the Summer 1970 showed grass seed present but in an ungerminated form. Excellent new growth on the strips was evident in the Fall 1970.

Grass growth was visible within one week after planting on Plot 16. By mid-Summer 1970, the vegetation was 5 feet tall and continued growth was expected. This test plot is shown in Figure 15.

Plot 17, treated with Coherex, developed a hard crust on the surface which penetrated approximately 4 inches deep with decreasing hardness. The condition of the test plot was essentially the same six months after application. This type of treatment would probably reduce any air pollution from the slurry lagoons to an insignificant level and would also reduce infiltration rate by increasing runoff.

All test plots on the refuse pile and slurry lagoons, except Plots 15 and 16, were destroyed during Phase II operations.

Refuse samples were taken from the test plots on the refuse pile only three times per month during the first six months of 1970. The samples were taken immediately below the interface between the refuse and the prepared cover, or from the first 4 inches of refuse in plots having no cover. One hundred grams of refuse were mixed with 500 ml distilled water and the resulting supernatant taken for chemical analysis. Due to the effect of the agricultural limestone used in the preparation of some of the plots, pH, acidity, and soluble iron analyses do not reflect the amount of oxidation products in the solid sample. Sulfate, however, was present in proportion to the amounts of pyrite oxidation products and should reflect any change in the oxidation rate, given a sufficiently long period of time.

For all of the plots, there was a considerable amount of scatter in the data and no apparent decrease in sulfate concentration in the refuse with time. However, due to the slow rate of flushing of the refuse by infiltrating water, detecting a definite change in oxidation product concentration in the refuse might require as many as five years, and no conclusion as to pyrite oxidation rate change can be drawn from these data. Hill[5] reports similar results in the Elkins mine drainage pollution control project. Table IX shows the average sulfate concentrations found in the samples taken from the plots shown during the six-month sampling period. The variation in these values from plot to plot is believed to be due to differences in the plots before covering and to have little relationship to the effect of the cover.

Samples of subsurface drainage from the test plots were taken once per week during the period February to May, 1970. No flows were detected in the underdrains before or after these dates and several plots showed no flow at any time. Samples

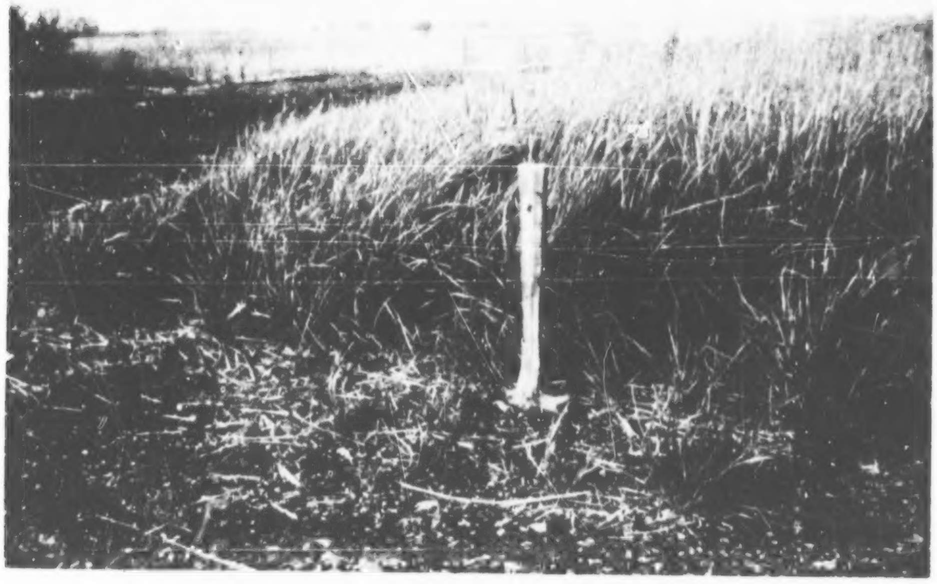

FIG. 14 GRASS COVER ON REFUSE PILE TEST PLOT #2

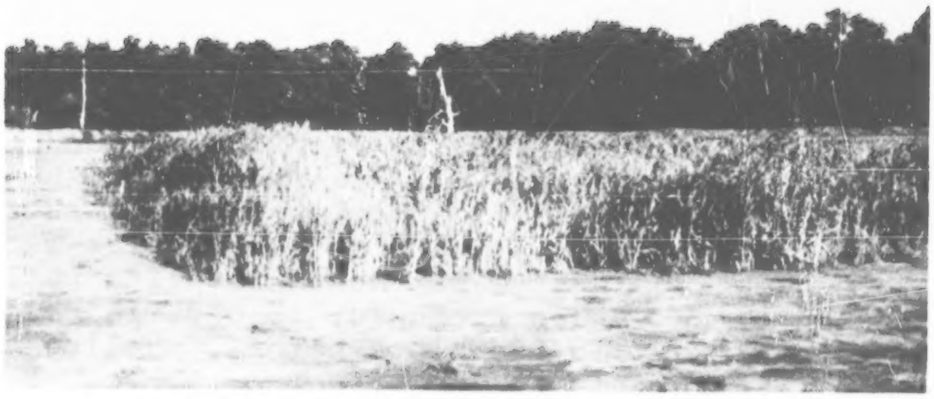

FIG. 15 GRASS COVER ON SLURRY LAGOON TEST PLOT #16

TABLE IX. SULFATE ANALYSES FROM REFUSE PILE TEST PLOTS*

Test Plot No.	Average Sulfate mg/l
1	1665
2	1752
7	2350
8	2193
9	2287
10	2035
12	2860
13	1834
14	2435

*Period - February 1970 through May 1970

were analyzed for pH, acidity, iron, and sulfate. As in the case of the solid refuse samples, there was no trend evident for meaningful sulfate content change with time for any of the test plots. Here, again, it is believed that several seasons might be required to flush the refuse significantly of oxidation products, even if oxidation of pyrite were completely stopped. Data shown in Table X.

TABLE X. AVERAGE ANALYSES OF SUBSURFACE DRAINAGE ON TEST PLOTS*

Test Plot No.	Acidity mg/l	pH	Sulfate mg/l	Total Iron mg/l	% Ferric
3	20,191	1.71	20,590	5445	62.7
4	10,026	2.25	10,391	2759	30.6
7	30,211	1.64	30,662	7880	52.7
8	35,710	1.29	37,518	9452	49.1
9	34,447	1.41	36,360	9476	50.5
10	29,018	1.35	30,341	7059	28.6

*Period - January 1970 through June 1970

The chemical analyses presented herein and in Appendix XI-H and XI-I are inconclusive in regard to an evaluation of the ability of any of the covers to retard or stop pyrite oxidation.

The most significant result of the experimental abatement measures applied to the test plots was the discovery that a grass cover could be established directly on highly acidic refuse material without the use of a topsoil base. However, because of the short duration of the test, it is not known to what extent direct application of limestone and fertilizer to refuse material can be effective in abating pollution by the vegetative cover technique. Whether a single application of limestone will be sufficient or whether the treatment will have to be repeated at some frequency has yet to be determined.

An attempt was made to estimate the costs of the experimental abatement measures developed in this study by extrapolating the basic data to a hypothetical site of approximately 100 acres. These data are summarized in Table XI, exclude grading, special drainage and engineering costs, and assume the use of conventional farm machinery. Since unit costs vary widely, a detailed breakdown of costs associated with each test plot is reported in Appendix XI-K.

There appears to be a decided incentive to further investigate limestone application directly to the graded refuse without topsoil addition as there are many instances where good topsoil

TABLE XI. COMPARATIVE COSTS OF VEGETATIVE TEST PLOTS

Plot No.	Barrier	Cover	Vegetative Results	Cost $/A	Remarks
1,2	None	Grass	Excellent	365	Limestone rototilled
3,4,5	None	Grass	Spotty	365	Limestone disked
6	Polyethylene Membrane and 4" of topsoil	Grass	Good	1749	Difficult to apply polyethylene
8	4" of topsoil	Grass	Spotty	660	Difficult to cover completely without leaving exposed patches of refuse
9	12" of topsoil	Grass	Good	1735	
10	24" of topsoil	Grass	Good	3345	
12	4" of sewage sludge	Grass	Good	820	
16	None	Grass	Good	210	Requires special equipment due to soft base material
17	None	Coherex	None	388	Requires special equipment due to soft base material

is a scarce and/or expensive commodity. Agricultural limestone is usually available locally at approximately $4-$6/ton spread on the site. At the rates used in the experimental Plots 1 and 2, i.e., 40 tons/acre, the cost of establishing a grass cover directly on the refuse material was estimated at approximately $365, excluding grading and certain other related costs. These costs can be broadly compared to those reported by others using topsoil covers. The Bureau of Mines[6] reports cost estimates from several sources for digging, short haulage and placing a 12 inch soil cover ranging from $0.23 to $0.36 per square yard ($1140-$1790/acre). This same reference reports "an Arizona copper producer with experience in covering two copper mill tailing ponds and an HEW report[7] estimating the cost of burying uranium mill tailings agree on a cost of $0.23 per square yard for digging, short hauling and placing a 12 inch soil cover. This would amount to $1113 per acre exclusive of costs for soil procurement."

During the course of this study, several waste-type alkaline materials were found to be available in the area. Similar situations may exist elsewhere and these can be tried to further reduce the costs. However, a word of caution is in order regarding the application of waste-type alkaline materials for mineral waste neutralization prior to establishing vegetative covers. Agricultural limestone is usually available locally at approximately $4-$6/ton spread on the site. A variety of alkaline-type waste materials may be available, either locally or at a relatively short distance from a site. Although the waste material may be inexpensive, sometimes even available at no cost, transporting and spreading this material can exceed the cost of agricultural limestone. In addition, the chemical potency of these materials may be quite low, requiring excessive quantities of weak material to furnish equivalent neutralizing power, further increasing the costs. And finally, toxic elements may be present in waste materials, and their effect on vegetative covers should be determined. Soil testing laboratories, university extension services, and the U.S. Department of Agriculture can be sources of valuable information in determining toxicity levels when matching plants with soils. However, it is important that the soil testing laboratory be made aware of the nature of the material being tested, otherwise a routine test will be made which can lead to erroneous conclusions. Each situation should therefore be carefully explored before deciding on a specific course of action.

In determining limestone requirements for the refuse-type material, a modified soil test was used as a guide. The procedure used was as follows:

> A select sample of refuse material containing particles <1 inch D. was crushed in a mortar and pestle to

approximately 20 mesh size. A 100-gram portion was mixed with distilled water and the volume adjusted to 400 cc. The pH of the slurry was determined and increments of agricultural limestone were added to the slurry until pH 5+ was obtained, at which point the rate of pH rise decreased sharply. The amount of limestone added was determined and this was then extrapolated to an application rate for the test plots. As an example, 7 grams of limestone was added to a 100-gram sample of refuse to raise the pH to 5.9 from 2.3. Refuse material had a bulk density of approximately 75 lb/cubic foot and tilling normally decreased this bulk density by 30% to 52 lb/cubic foot. One acre of refuse tilled to a depth of 6 inches weighed:

$$\frac{43{,}560\ \text{ft}^2}{\text{acre}} \times 0.5\ \text{ft} \times \frac{52.5\ \text{lb}}{\text{ft}^3} = 1{,}150{,}000\ \text{lb/acre}$$

The amount of limestone necessary to neutralize 1 acre of refuse was:

$$\frac{1{,}150{,}000\ \text{lb refuse}}{\text{acre}} \times \frac{7\ \text{grams limestone}}{100\ \text{grams refuse}} \times \frac{1\ \text{ton}}{2000\ \text{lb}}$$

$$= 40\ \text{tons/acre}$$

It is apparent that the technique used here considers only the soluble acid present in the sample, and assumes that further oxidation of the remaining pyrite will not take place. This may or may not be true.

Additional work in this area of soil testing for refuse piles appears justified. The University of Illinois is reported to be doing research in chemical characterization of high sulfur coastal plain soils using the sulfur fractionation procedure developed there.

Phase II of this project is currently underway. The refuse pile has been graded, special drainage lines have been installed and three giant test plots established with different thicknesses of earth planted to grasses. Four automated monitoring stations have been installed and these will be used to collect data during the next year from which the effectiveness of the abatement technique will be determined.

The slurry lagoons have also been treated with abatement measures. One-half of the slurry lagoons was treated with limestone and fertilizer and planted to grasses. The other half was treated with the Coherex chemical stabilizer and may be planted to grasses later. The water in the ponds was neutralized and drained and the area occupied by the ponds planted to grass. The dikes were opened to allow any runoff to flow into Walker Creek rather than be impounded. Two monitoring stations were also installed at the slurry lagoons.

A final report covering Phase II will be issued after the monitoring program is completed.

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* * *

The primary objective of this large scale project was to demonstrate practical methods of abating pollution from coal mine refuse piles. The demonstration of at-source control methods such as this is an important element of the total Environmental Protection Agency Mine Drainage Pollution Control Program. This project was conducted under the direction of the Pollution Control Analysis Section, Ernst P. Hall, Chief, and Donald J. O'Bryan, Project Manager, with Eugene E. Chaudoir, of the EPA Indiana District Office serving as Project Officer.

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APPENDIX XI-A

RAINFALL DATA

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RAINFALL, INCHES

Date 1969	April	May	June	July	August
1	-	0	0	1.90	0
2	-	0	0	0.40	0
3	-	0	0	0.20	0
4	-	0	0	0	0
5	-	0	0	0	0
6	-	0	0	0.15	0
7	-	0.25	0	1.30	0
8	-	0.20	0.05	0	0
9	-	0	0.10	0.05	0
10	-	0	0	0	0
11	-	0	0	0.15	0
12	-	0	0	0	0
13	-	0.50	0.20	1.00	0
14	-	0	0.85	0	0
15	-	0	0.05	0	0
16	-	0	0	0	0
17	-	0.55	0	0	0
18	0.10(1)	0.35	0.20	0	0.50
19	0.05	0	0	0	0
20	0	0	0	0.50	0.40
21	0	0	0	1.25	0
22	0	0	1.70	1.55	0
23	0	0	0.20	0	0
24	0	0	0.30	1.55	0
25	0	0	0	0	0
26	0	0	0	0	0
27	0	0	0.05	0.40	0
28	0	0	0.75	0	0
29	0	0	0	0	0
30	0	0	1.45	0	0
31		0		0.05	0
Total	0.15"	1.85"	5.90"	10.45"	0.90"

(1) Started operation of rain gage on 4/18/69

RAINFALL, INCHES

Date 1969	September	October	November	December
1	0	0.10	0	0
2	0	0	0	0
3	0.15	0	0.05	0
4	0.75	0	0	0
5	0	0	0	0
6	0.40	0.95	0	0.60
7	0.25	0.10	0	0.20
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0.10
11	0	0.40	0	0.15
12	0	0	0	0
13	0	0.15	0	0
14	0	0	0	0
15	0.05	0	0	0
16	0.65	0	0	0
17	0.15	0	0.45	0
18	0	0.10	0.85	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	0.10	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
27	0.10	0	0	0
28	0	0	0	0
29	0	0	0	0
30	0	0	0	0
31		0		0
Total	2.60"	1.80"	1.35"	1.05"

RAINFALL, INCHES

Date 1970	January	February	March	April
1	0.10	0.35	0.20	0
2	0	0.10	1.30	0.40
3	0	0	0.35	0
4	0	0	0.50	0
5	0	0	0	0
6	0	0	0	0
7	0	0.55	0	0
8	0	0.20	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0.05	0
12	0	0	0.25	0.75
13	0	0	0	0
14	0.25	0	0	0
15	0.10	0	0	0
16	0	0	0	0
17	0	0	0.55	0.25
18	0	0	0.05	0.15
19	0	0	0	1.35
20	0	0	0	0
21	0	0	0.10	0
22	0	0.45	0.15	0
23	0	0	0.05	0.10
24	0	0	0.05	0.15
25	0	0	0.95	0
26	0	0	0.05	0
27	0	0	0	0.20
28	0.85	0	0	0.45
29	0		0	0
30	0		0	0.15
31	0		0.05	
Total	1.30"	1.65"	4.65"	3.95"

RAINFALL, INCHES

Date 1970	May	June	July	August	September
1	0.45	1.25	0	0	0
2	0	0.55	0	0	0
3	0	1.35	0.60	0	0
4	0	0.20	0	0	0
5	0	0	0	0.70	0
6	0	0	0	0.05	0
7	0	0	0	0	0
8	0	0	0	0.45	0
9	0.10	0	0	0.40	0
10	1.35	0	0	0	0
11	0.90	0	0	0.40	0
12	0	0	0	0	0
13	0	0.35	0	0	0.35
14	0	0	0	0	0
15	0.60	0	0	0	0
16	0	0	0	0	0.15
17	0	0	0	0.95	0.10
18	0	0	0	0	1.25
19	0	0.15	0.50	0	0
20	0	0.20	0	0	0
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0.15	0	0	0.55
24	0	0.05	0	0	0
25	0.20	0	0	0	0
26	0	0	0	0	0.95
27	0	0	0	0	0
28	0	0	0	0	0(1)
29	0.40	0	0	0	-
30	0.25	0	0	0	-
31	0.25		0	0.45	
Total	4.50"	4.25"	1.10"	3.40"	3.35"

(1) Collection of rain gage data terminated on 9/28/70

APPENDIX XI-B

WATER LEVEL RATING TABLE

AREA 6 FLUME

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FLUME 1.5 FEET DEEP AT FLOW POINT NO. 6

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	-	-	.002	.003	.005	.008	.011	.014	.018	.023
0.1	.028	.033	.038	.044	.051	.058	.066	.073	.081	.090
0.2	.099	.108	.119	.129	.140	.152	.164	.177	.191	.204
0.3	.218	.234	.249	.266	.282	.298	.317	.335	.354	.374
0.4	.393	.414	.436	.459	.481	.505	.528	.554	.578	.604
0.5	.631	.658	.685	.714	.744	.775	.805	.835	.868	.900
0.6	.934	.968	1.00	1.04	1.07	1.11	1.15	1.19	1.23	1.27
0.7	1.31	1.35	1.39	1.44	1.48	1.53	1.57	1.62	1.67	1.71
0.8	1.76	1.81	1.86	1.91	1.96	2.02	2.07	2.13	2.18	2.24
0.9	2.30	2.35	2.40	2.47	2.53	2.58	2.65	2.71	2.78	2.85
1.0	2.91	2.98	3.04	3.12	3.20	3.26	3.34	3.40	3.48	3.56
1.1	3.63	3.71	3.80	3.86	3.95	4.04	4.11	4.20	4.28	4.37
1.2	4.45	4.54	4.63	4.71	4.80	4.89	4.99	5.09	5.19	5.29
1.3	5.38	5.48	5.57	5.67	5.76	5.86	5.97	6.08	6.19	6.28
1.4	6.40	6.50	6.61	6.72	6.84	6.95	7.05	7.18	7.28	7.40

APPENDIX XI-C

DAILY MAXIMUM AND MINIMUM TEMPERATURES

AREA 6

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
Dec. 1969	Max	Min	Max	Min	Max	Min
12	--	24	34	--	35	33
13	60	26	40	29	41	35
14	38	28	39	33	39	37
15	31	17	32	27	36	33
16	39	14	28	25	38	32
17	42	18	28	25	36	33
18	52	24	38	28	38	34
19	37	18	30	26	36	32
20	28	14	26	25	34	32
21	26	24	27	26	32	32
22	36	22	27	26	33	32
23	32	20	27	26	32	31
24	24	12	26	25	32	30
25	32	20	26	25	32	30
26	27	7	26	25	31	28
27	27	12	25	24	30	28
28	30	25	26	25	30	30
29	30	23	26	26	30	30
30	26	22	26	26	30	30
31	27	21	27	26	30	30

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
Jan. 1970	Max	Min	Max	Min	Max	Min
1	26	17	27	27	30	29
2	34	2	28	27	31	29
3	20	2	25	24	29	27
4	39	1	26	22	31	28
5	39	4	26	22	30	26
6	8	-4	22	18	26	23
7	6	-4	18	13	24	22
8	2	-4	13	10	22	20
9	11	-4	14	10	22	19
10	24	-4	17	9	22	18
11	30	22	21	17	24	22
12	35	4	22	19	22	21
13	40	1	22	18	26	20
14	51	13	24	18	28	23
15	56	18	25	21	28	24
16	46	22	24	23	26	25
17	35	7	25	21	27	26
18	11	-1	21	13	26	23
19	16	0	17	13	24	21
20	15	-5	18	6	22	21
21	13	-5	12	2	22	18
22	21	-3	15	4	20	17
23	25	7	18	15	19	17
24	42	11	22	15	26	19
25	60	31	29	22	25	23
26	42	27	28	26	24	23
27	54	30	35	26	26	23
28	72	45	49	31	43	25
29	45	19	42	27	37	28
30	46	17	27	26	31	27
31	55	24	35	27	33	28

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
Feb. 1970	Max	Min	Max	Min	Max	Min
1	48	28	35	28	32	30
2	36	-2	33	24	30	24
3	10	-4	18	10	24	22
4	32	1	23	10	26	22
5	48	28	29	23	30	26
6	39	28	30	27	26	24
7	48	34	36	24	31	27
8	42	26	26	24	31	29
9	28	22	36	26	29	27
10	46	21	35	27	31	27
11	44	23	29	28	29	28
12	37	20	29	28	29	26
13	34	22	29	26	26	25
14	23	16	24	22	24	21
15	27	5	24	21	24	22
16	43	3	28	22	26	22
17	45	14	27	23	29	24
18	63	24	45	27	35	27
19	34	18	30	27	29	27
20	26	11	29	24	29	25
21	62	21	36	24	34	24
22	44	33	35	31	31	30
23	59	28	49	30	36	28
24	46	29	40	32	34	31
25	42	14	38	22	34	27
26	41	12	27	22	31	26
27	59	28	42	30	36	28
28	51	29	39	30	34	30

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
March 1970	Max	Min	Max	Min	Max	Min
1	53	44	45	38	36	33
2	68	51	54	45	43	36
3	60	52	52	51	43	41
4	54	31	51	34	42	36
5	55	28	46	33	40	36
6	64	28	52	32	42	34
7	63	30	50	36	42	35
8	72	33	57	36	45	36
9	55	35	48	38	41	38
10	46	27	42	32	38	36
11	32	26	32	31	36	33
12	32	26	31	30	34	33
13	37	22	32	27	32	28
14	33	20	29	28	30	29
15	40	18	32	26	30	28
16	40	18	33	26	36	29
17	29	25	30	29	30	29
18	42	28	38	28	31	29
19	42	29	37	31	32	31
20	42	29	38	30	30	28
21	43	25	38	30	32	38
22	55	31	35	32	36	30
23	38	30	34	32	34	30
24	58	29	49	29	38	29
25	56	34	46	35	40	35
26	47	30	42	30	36	33
27	60	25	48	28	39	31
28	50	28	42	33	37	33
29	42	26	41	32	35	32
30	37	32	42	34	36	33
31	63	31	51	36	41	32

April 1970	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
	Max	Min	Max	Min	Max	Min
1	53	35	45	39	40	38
2	51	31	43	35	39	34
3	70	31	54	34	44	34
4	54	33	48	42	44	34
5	64	28	52	35	44	45
6	64	38	54	40	45	38
7	69	30	50	38	46	37
8	79	41	60	42	50	41
9	73	45	61	48	51	44
10	81	43	66	46	53	48
11	82	43	66	48	55	46
12	71	46	59	51	52	47
13	58	40	54	45	48	45
14	47	40	45	43	45	43
15	72	34	59	40	49	42
16	84	51	71	51	56	46
17	84	60	66	60	55	52
18	65	53	58	53	53	50
19	69	47	62	50	55	50
20	76	44	59	48	50	48
21	79	40	63	47	53	46
22	76	56	63	53	54	50
23	60	49	62	53	54	49
24	84	50	66	52	55	49
25	68	48	60	52	54	50
26	84	57	72	57	58	52
27	88	60	70	60	60	57
28	87	69	75	66	62	58
29	83	68	74	68	62	60
30	87	66	77	68	64	60

May 1970	48" Above Surface °F Max	48" Above Surface °F Min	3" Below Surface °F Max	3" Below Surface °F Min	20" Below Surface °F Max	20" Below Surface °F Min
1	68	42	66	52	62	56
2	67	37	63	48	56	50
3	78	34	70	46	58	50
4	88	47	66	54	62	54
5	90	47	79	57	64	55
6	71	47	70	56	61	56
7	86	47	77	56	63	55
8	86	56	78	64	63	58
9	85	62	73	48	63	62
10	84	56	75	64	64	61
11	83	62	73	64	62	60
12	90	68	80	68	66	61
13	94	70	84	70	69	64
14	92	63	84	70	69	62
15	88	52	78	60	68	60
16	74	51	66	58	62	58
17	87	68	60	55	65	57
18	87	52	80	60	66	59
19	87	56	87	63	70	61
20	93	57	88	66	62	64
21	97	60	92	78	73	66
22	96	67	91	72	74	78
23	99	64	88	79	64	58
24	98	66	82	74	76	69
25	98	58	88	68	75	68
26	89	52	85	64	72	66
27	89	56	86	66	72	66
28	94	64	91	70	74	68
29	91	67	86	70	74	70
30	84	66	78	70	70	68
31	80	68	73	70	68	68

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
June 1970	Max	Min	Max	Min	Max	Min
1	82	67	73	68	67	66
2	80	65	71	64	66	64
3	74	62	66	64	64	62
4	71	60	64	61	61	60
5	64	60	60	60	60	58
6	86	57	74	61	64	60
7	94	53	83	60	69	60
8	93	61	84	66	70	63
9	92	62	85	68	71	65
10	93	64	83	68	71	66
11	82	66	86	70	72	67
12	86	69	78	72	70	68
13	90	66	84	70	72	67
14	100	68	92	73	75	69
15	90	67	84	72	72	69
16	94	69	87	83	73	67
17	101	84	93	76	76	71
18	96	78	92	78	78	74
19	78	60	74	78	70	68
20	90	58	84	65	72	67
21	74	56	75	66	69	66
22	90	52	84	62	71	64
23	93	54	90	66	74	66
24	100	64	94	72	76	69
25	93	66	91	73	76	70
26	94	66	82	76	76	72
27	92	57	90	70	76	70
28	91	58	89	70	76	70
29	97	61	93	71	77	70
30	102	67	97	76	80	72

	48" Above Surface °F		3" Below Surface °F		20" Below Surface °F	
July 1970	Max	Min	Max	Min	Max	Min
1	111	71	101	79	83	75
2	111	66	105	104	86	78
3	106	71	93	78	82	76
4	81	62	84	62	78	74
5	90	58	85	69	78	75
6	92	56	82	67	78	69
7	92	62	91	72	78	72
8	101	68	95	76	80	74
9	92	62	92	74	79	74
10	100	62	90	74	80	72
11	104	65	100	77	82	75
12	101	68	99	79	83	76
13	104	66	100	79	84	86
14	102	69	99	80	84	78
15	99	66	92	78	82	78
16	102	62	96	73	82	74
17	96	62	90	76	82	76
18	99	63	95	78	82	78
19	92	70	85	76	80	77
20	76	60	75	67	78	76
21	88	52	83	63	74	66
22	87	56	85	65	74	68
23	89	66	87	73	75	71
24	97	63	95	73	79	71
25	102	67	99	77	82	74
26	98	74	98	82	82	78
27	99	71	96	81	82	77
28	98	72	96	81	82	77

APPENDIX XI-D

SURFACE FLOW AND WATER QUALITY DATA

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FLOW POINT NO. 1

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
4/16						0	780	702	5,789
4/23			2.6						
5/6			2.45	21,450		0	6,842	5,881	25,848
5/7			2.4	15,150		0	4,330	3,220	18,420
5/8	09:15		2.1	21,100		0	6,708	5,210	26,400
5/8	10:15		2.3	18,750		0	5,724	4,530	23,010
5/9	09:00		2.35	18,850		0	6,093	4,852	23,340
5/11	19:00		2.5	19,400		0	5,937	5,022	22,500
5/14	08:00		2.4	8,975		0	2,571	1,608	10,752
5/14	11:00		2.45	6,550		0	1,474	1,018	8,352
5/14	17:00		2.4	6,690		0	1,838		8,688
5/18	10:00		2.35	3,500		0	9,771	604	4,877
5/18	16:00		2.35	8,250		0	2,616	1,983	10,560
5/19	16:30		2.2	7,900		0	2,234	1,802	9,840
5/20	09:00		2.3	8,850		0	2,340	1,874	10,152
6/9	09:00		2.4	23,500	20,160	0	7,871	5,903	30,480
6/9	11:00		2.45	25,350	21,840	0	8,870	6,570	33,312
6/9	13:00		3.5	26,500	22,400	0	9,000	6,641	34,176
6/9	15:00		3.45	27,500	22,960	0	9,210	6,735	34,560
6/13	08:00		2.3	10,750	9,856	0	2,292	1,297	12,816
6/18	08:15		2.25	10,950	11,100	0	3,019	1,737	
6/18	08:30		2.25	8,725	9,075	0	2,194	1,101	
6/18	08:45		2.3	7,500	8,230	0	1,880	890	
6/18	09:00		2.25	7,250	7,840	0	1,688	702	
6/18	09:15		2.25	8,500	9,070	0	2,214	1,050	
6/18	09:30		2.25	8,850	9,180	0	2,236	1,275	
6/18	09:45		2.25	8,475	8,960	0	2,142	1,073	
6/18	15:00		2.25	19,450	19,900	0	6,015	4,584	
6/22	08:45		2.55	3,975	2,250	0	455	112	
6/22	09:00		2.5	2,400	4,050	0	492	145	
6/22	09:15		2.5	2,700	4,330	0	592	181	
6/22	09:30		2.45	3,100	4,875	0	730	251	
6/22	09:45		2.4	3,400	5,150	0	817	311	
6/22	13:30		1.9	7,750	9,800	0	2,050	492	
6/22	13:45		2.25	5,750	8,520	0	1,540	672	
6/22	14:00		2.35	5,300	7,280	0	1,400	593	
6/22	14:15		2.3	5,550	7,500	0	1,410	601	
6/24	07:50		2.3	2,675	5,260	0	620	292	
6/24	08:30		2.25	3,815	6,610	0	923	454	
8/4	11:30	2.4	2.4	14,700	16,700	0	4,780	4,140	
8/6		3.0		15,400		0	4,880	3,900	
8/12		4.0	2.55	16,050	17,800	0	5,225	4,350	
8/14			2.55	17,800	20,950	0	5,700	4,660	
8/14			2.45	21,600	24,100	0	7,040	6,650	
8/15			3.45	15,400	18,600	0	4,925	4,920	
8/19			2.35	10,850	12,700	0	3,170	1,590	
8/20	16:52		2.3	14,350	15,904		4,350	3,150	
8/20	17:17		2.2	15,400	14,630		4,245	2,540	
8/20	17:21		2.1	12,950	13,100		3,320	1,585	
8/20	17:26		2.15		12,100				
8/20	17:30		2.15	9,750	10,700		2,320	895	
8/20	17:36		2.2		9,860				
8/20	17:41		2.2	7,900	9,350		1,800	630	
8/20	17:45		2.2		8,960				
8/20	17:50		2.2		8,620				
8/20	17:55		2.2	7,200	8,830		1,565	565	
8/20	18:00		2.2	6,250	8,230		1,400	485	
8/20	18:06		2.2		8,430				
8/20	20:30		2.2	7,000	8,960		1,625	708	
8/21		2.0	2.3	11,500	11,550	0	3,040	1,420	
8/25		2.0	2.5	12,550	15,000	0	4,310	3,945	
8/28		1.1	2.5	15,500	18,200	0	4,970	3,930	
9/3		1.7	2.1	14,200	17,050	0	5,360	4,790	
9/4		8.6	2.6	1,500	3,830	0	384	127	
9/10		2.2	2.4	4,350	6,950	0	1,287	917	
9/12		1.2	2.4	6,140	9,620	0	1,825	1,315	
9/16		0.75	2.60		13,930	0			
9/18		1.4			8,620				
9/29		2.0	2.4	14,700	14,000	0	4,310	2,460	
10/2		1.3	2.55	13,750	13,200	0	4,550	3,575	
10/6		0.26	2.45	17,000	18,500	0	5,570	4,360	
10/7	08:30		2.25	5,700	6,830	0			

FLOW POINT NO. 1

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
10/9		0.62	2.5	5,800	8,070	0	1,470	1,145	
10/13		1.4	2.45	7,890	8,630	0	2,485	2,090	
10/13	12:15		2.5	11,600	8,850		2,740	2,280	10,780
10/13	14:30		2.15	6,150	7,450		1,600	780	7,380
10/15			2.2	7,300	7,340	0	2,080	1,385	9,120
10/20		1.5	2.65	12,065	12,200	0	4,050	3,420	15,000
10/27		0.32	2.7	14,250	12,650	0	4,750	4,030	19,100
11/4		0.79	2.5	12,000	10,100	0	4,114	3,667	14,880
11/11		1.5	2.7	425	4,930	0	1,320	1,200	5,136
11/14		0	2.75	11,700	8,630		4,150	3,580	10,940
11/18			2.3	3,000	3,300		659	403	3,528
11/21		3.2			6,270		2,062	1,890	3,760
11/25		0.43	3.48		9,750		3,430	3,205	12,800
12/5		0.86	3.56	13,050	9,025		4,575	4,290	15,150
12/9				3,800	3,700		915	591	4,650
12/11	08:50			8,700			2,720	2,440	9,850
12/11	10:30			10,850			3,660	3,430	10,128
12/12				8,400	5,712		2,560	2,280	9,800
12/16				11,450	9,700		3,920	3,730	10,490
12/19				12,150	8,625		4,010	3,225	14,150
12/23				11,600	6,500		3,830	3,755	10,500
1970									
1/5			2.4	11,600	9,460		3,730	3,560	12,950
1/14			2.8	16,700	13,450		5,675	5,550	19,200
1/16			2.9	13,275	9,960		4,370	4,260	9,720
1/26		6.7	2.2	11,200	8,620		3,510	2,820	10,000
1/28		0.92	2.8	7,000	8,000		2,280	2,070	8,900
2/2		12	2.35	6,000	4,480		1,765	1,340	7,030
2/5		80	2.6	3,820	4,250		950	840	4,900
2/5	14:05	80	2.6	5,100	4,250		950	839	3,670
2/5	15:05	80	2.4	3,570	4,310		950	744	4,410
2/5	16:05	80	2.5	4,300	4,600		1,185	894	5,420
2/9		15	2.45	9,075	7,615		2,710	2,370	9,504
2/13		3.7	2.55	17,425	14,700		5,649	5,478	19,295
2/17		80	2.6	5,400	5,380		1,540	1,284	6,380
2/18	09:50		2.4	4,580	5,090		1,150	760	5,380
2/18	12:05		2.4	5,320	6,610		1,472	984	6,570
2/20		4.6	2.6	15,020	10,975		5,250	5,050	11,700
2/25		2.6	2.7	15,420	10,300		5,030	4,785	9,700
2/27		1.6	2.6	16,275	13,800		5,270	5,100	18,630
3/3		20	2.25	9,250	9,300		2,610	1,710	9,750
3/4	09:45		2.2	3,825	4,480		917	4,092	
3/4	13:10		2.0	6,700	6,380		1,811	910	
3/4	16:00		2.0	10,600	9,060		2,974	1,845	
3/6		12	2.3	16,950	13,450		5,090	4,450	18,400
3/8		4.3							
3/10		2.2	2.4	21,800	14,800		6,680	6,300	19,550
3/12	15:15	12	3.1	11,850	8,300		3,620	3,240	13,380
3/13	15:00	15	2.4	20,300	7,620		5,230	3,755	20,700
3/13		15	2.4	7,500	7,620		2,290	1,800	8,625
3/18	09:15	34	2.4	9,240	7,210		2,770	2,420	10,080
3/18	13:30		2.6	5,750	5,370		1,565	1,185	6,490
3/18	16:35			3,500	4,040		960	559	4,300
3/19	11:20		2.4	9,320	7,840		2,790	2,300	11,000
3/19	15:20		2.20	9,250	7,270		2,620	2,030	10,300
3/20		7	2.5	14,500	10,850		4,580	4,120	16,700
3/24		3.7	2.4	15,500	13,550		5,320	4,960	19,150
3/25	08:15		2.4	4,900	4,940		1,356	867	6,060
3/25	13:00		2.25	7,560	7,500		2,220	1,641	9,000
3/25	15:45		2.3	9,370	8,730		2,880	2,360	9,440
3/30		6.6	2.4	17,800	13,832		5,625	5,250	23,200
4/2		2.0	2.5	16,900	12,750		5,100	4,720	18,400
4/7		5	2.3	19,100	14,550		6,400	6,020	22,700
4/12		3.0	2.5	21,900	17,620		6,820	6,440	25,500
4/14		1.1	3.1	14,900	10,090		4,880	4,490	24,000
4/16		1.5	2.4	18,200	17,600		5,780	5,500	21,800
4/19	14:00		2.4	4,150	5,490		1,035	648	5,060
4/19	17:00		2.45	5,000	6,160		1,361	973	6,000
4/21		1.1	2.5	14,300	12,370		4,160	3,910	16,600
4/23		1.9	2.5	15,250	12,200		4,940	4,480	10,650

FLOW POINT NO. 1

Date 1970	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
4/28		7.5	2.4	8,200	9,400		2,100	1,880	8,500
4/30		1.8	2.45	16,900	16,800		5,200	4,700	18,800
5/5		2.6	2.5	19,800	17,100		5,930	5,600	21,700
5/11		14	2.8	7,700	8,240		7,100	1,830	8,420
5/15	14:30		2.7	15,750	13,340		4,700	4,371	16,000
5/15	16:15		2.5	5,750	6,500		1,420	637	
5/19		2.3	2.9	19,000	17,950		5,900	5,500	22,100
5/25	15:15			22,600	19,600		7,250	6,100	23,550
6/2	01:45			11,200	10,980		3,195	3,045	12,100
6/2	04:00			2,500	4,370		581	436	3,165
6/3	09:15			19,600	16,800		4,570	1,260	19,500
6/3	09:30			1,000	2,075		123	73	
6/3	10:50			2,500	3,810		576	447	
6/3	13:45			2,000	3,640		391	185	2,590
6/3	15:50			4,600	6,500		1,070	810	5,380
6/8		1.2		16,900	15,700		5,400	4,730	19,100
6/15	14:15	0.86	2.15	20,500	20,820		6,730	6,420	23,350
6/22		1.1	2.45	20,100	19,320		6,370	6,260	24,600
6/25		0.87	2.3	18,800	17,900		5,430	5,040	20,650
7/1		0.42	2.5	24,400	25,200		7,100	6,780	27,800
7/6		1.1	2.3	21,100	19,050		6,600	6,200	25,400
7/13		0.27	2.8	19,700	20,600		5,880	5,810	22,650
7/17		0.07	2.25	26,600	22,000		8,230	7,330	29,600
7/21		0.31	2.2	22,000	19,000		6,820	6,350	24,950
7/24		0.47	2.2	25,300	21,000		7,890	7,390	29,200

FLOW POINT NO. 2

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
3/26			2.3	14,640					
4/16			2.4	8,200		0	3,589	2,265	17,520
5/6			2.3	16,500		0	1,789	9	10,830
6/24	07:55		2.1	7,065	8,850	0	3,913	22	19.584
6/24	08:35		2.1	9,150	9,750	0	1,475	272	
7/2	05:08		2.15	3,625	5,830	0	1,990	185	
7/2	08:48		2.15	4,300	6,050	0	716	72	
7/2	09:05		2.15	4,650	6,500		850	24	
7/2	09:30		2.15	5,050	6,720		943	36	
7/2	09:58		2.25	1,850	4,420		968	73	
7/2	10:10		2.25	2,250	4,870		291	123	
7/2	10:48		2.1	4,300	6,500		411	124	
7/2	10:55		2.1	3,750	6,160		876	49	
7/2	11:57		2.1	4,150	6,130				
7/2	14:00		2.05	4,210	6,730		823	119	
7/2	15:00		2.05	4,075	6,780		843	74	
7/2	15:45		2.15	4,150	6,730				
7/2	16:30		2.1		6,730				
7/21	15:05	422			5,250		810	58	
7/21	15:10	422			5,370			34	
7/21	15:15	435			5,850			48	
7/21	15:30	337			6,570			36	
7/21	16:00	238			7,980			101	
7/21	16:25	184			8,270			235	
7/21	17:00	144			8,650			268	
7/21	19:30	49			8,280			385	
7/21	20:00	45			8,370			257	
7/22	09:12	337			5,050			280	
7/22	09:34	247			5,180				
7/22	09:46	220			5,180				
7/22	09:56	211			5,280				
7/22	10:06	193			5,600				
7/22	14:30	45			6,060				
7/22	15:30	36			6,250				
7/22	16:30	27			6,830				
7/22	19:40	9.0			6,400				
7/22	20:15	9.0			6,380				
7/23	08:30	22			8,800				
7/23	10:30	18			9,320				
7/23	13:00	18			9,420				
7/23	17:00	49			9,800				
7/24	09:15	256			13,600				
7/24	16:25	4.5			8,820				
7/24	17:00	20			7,200				
7/24	17:15	36			6,900				
7/24	17:45	31			6,500				
7/25	08:30				9,970				
7/25	11:12				10,360				
9/4	09:30	12	2.15	8,900	9,500	0	2,210	498	
10/13	12:15		2.1	3,675	10,200		2,555	943	13,320
10/13	14:33		2.0	13,000	11,650		3,045	788	15,550
12/11	08:50			16,100			3,690	1,930	10,950
12/11	10:30			17,650			3,900	1,910	10,610
1970									
2/5	14:10	3.0	2.35	7,500	5,040		1,410	917	8,200
2/5	15:10	10	2.2	7,150	6,440		1,340	660	7,870
2/5	16:10	6.7	2.15	7,250	5,860		1,395	716	7,960
2/18	09:45		2.2	12,050	9,300		2,480	1,362	10,120
2/18	12:10		2.2	14,350	11,550		2,880	1,495	15,510
3/3	10:00		2.2	9,150	8,575		1,655	592	9,030
3/4	09:35		2.1	9,100	7,120		1,621	537	
3/4	13:05		2.2	8,700	6,600		1,655	604	
3/4	16:05		2.0	11,600	8,240		2,225	928	
3/12	15:15	8.6	2.3	20,300	10,750		5,230	3,755	20,700
3/13	15:00	4.6	2.2	20,500	13,000		5,500	3,900	22,300
3/18	09:10	7.5	2.2	13,950	8,280		3,400	2,330	15,000
3/18	13:40		2.3	13,250	8,900		3,100	1,840	10,250
3/18	16:35		2.25	9,250	6,250		1,685	895	8,650
3/19	11:15		2.35	18,500	11,410		4,440	2,900	18,600
3/19	15:25		2.0	17,720	10,610		4,150	2,580	17,500

FLOW POINT NO. 2

Date 1970	Time	Flow GPM	pH	Net Acidity mg/1	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/1	Total Iron mg/1	Ferrous Iron mg/1	Sulfate mg/1
3/25	08:50		2.6	9,570	7,500		2,470	1,540	9,940
3/25	13:15		2.2	8,710	7,390		1,920	1,125	9,870
3/25	15:45		2.2	10,100	8,170		2,270	1,310	11,510
4/1	16:30		2.5	20,600	13,900		5,970	4,730	11,700
5/15	14:30		2.2	14,125	11,200		3,060	2,120	15,260
5/15	16:15		2.1	9,200	8,180		1,950	626	
5/25	15:15			24,200	15,450		3,180	1,185	23,610
6/2	13:45			18,600	14,400		4,230	3,280	20,750
6/2	16:00			8,100	8,960		1,605	850	8,540
6/3	09:20			2,600	3,980		475	241	2,980
6/3	10:50			5,500	5,890		934	525	
6/3	13:40			5,400	6,280		977	392	6,920
6/3	15:45			10,500	10,400		2,070	1,145	11,800

FLOW POINT NO. 3

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
3/26			2.4	23,680		0	6,985	6,578	28,416
4/16						0	6,932	6,630	30,144
5/6			2.3	30,500		0	9,011	8,631	37,800
7/21				19,000	20,300		6,200	5,980	
8/4	11:30		2.9	16,500	17,350	0	5,320	5,230	
8/12		3.0	2.9	15,150	16,100	0	4,920	4,760	
8/14			2.95	15,400	16,550	0	4,900	4,760	
8/19			3.0	14,800	16,500	0	4,980	4,860	
8/21			3.05	15,000	15,700	0	4,770	4,620	
8/25			3.1	15,450	15,450	0	4,860	4,710	
8/28			2.95	16,500	15,960	0	4,920	4,780	
9/3			2.6	15,250	16,100	0	5,025	4,880	
9/10		3.0	2.9	17,690	16,400	0	4,990	4,900	
9/12		1.7	3.0	15,500	15,900	0	5,080	4,990	
9/16		1.8	3.05		15,600				
9/18		1.9			15,250				
9/29		1.9	2.6	16,550	15,450	0	5,240	5,140	
10/2		1.9	3.0	16,250	14,450	0	5,220	5,080	
10/6		2.4	2.9	15,450	15,500	0	5,020	4,875	
10/9		1.6	3.1	15,550	14,800	0	5,140	5,010	
10/13		2.1	2.9	15,150	16,130	0	4,890	4,780	
10/15			2.9	14,950	11,870	0	5,060	4,960	18,720
10/20		1.7	3.15	15,750	13,700	0	5,060	4,930	18,600
10/27		1.7	3.1	15,650	13,000	0	5,080	4,980	19,820
11/4		1.5	3.0	15,500	11,450	0	5,110	4,920	19,200
11/11		1.4	2.95	15,500	11,750	0	4,990	4,680	10,300
11/14		1.2	3.2	15,250	9,620		4,960	4,760	10,580
11/18			2.1	12,600	9,700		3,460	2,550	11,038
11/21		1.1	2.7		10,720		4,950	4,600	4,475
11/25		0.97	3.48		11,100		4,400	4,300	18,000
12/5		1.0	3.68	15,900	9,750		4,950	4,780	17,900
12/9		1.1		15,500	9,180		5,030	4,900	10,350
12/12		0.93		16,150	8,848		5,030	4,900	10,460
12/19		0.88		16,800	10,200		5,120	4,960	18,400
12/23				16,700	7,950		5,050	4,780	10,550
1970									
1/5		0.92	2.6	16,350	11,650		5,070	4,810	18,240
1/14		1.4	2.75	13,250	11,000		4,000	3,720	10,550
1/16		1.4	2.7	13,225	9,840		3,960	3,720	9,880
1/26		1.2	2.55	16,200	10,400		5,790	4,660	9,750
1/28		1.4	2.6	14,350	12,650		4,290	3,920	17,100
2/2									
2/5		2.7	2.3	11,240	8,850		3,240	2,620	9,220
2/9		0.94	2.5	16,900	11,200		5,100	4,830	18,240
2/13		1.6	2.75	19,250	14,570		5,745	5,658	19,350
2/17		60	2.4	9,800	7,840		2,820	2,110	11,100
2/20		1.9	2.75	18,520	10,420		6,350	6,190	19,050
2/25		1.5	2.9	21,100	11,200		6,550	6,430	19,350
2/27		2.2	2.75	21,600	15,480		6,620	6,480	19,100
3/3			2.5	19,150	14,350		5,680	5,090	20,250
3/6		3.4	2.6	22,100	15,100		6,500	6,260	26,800
3/8		3.0							
3/10			2.7	24,700	15,250		7,530	7,340	19,350
3/13		4.0	2.6	25,250	14,650		7,450	7,280	23,800
3/20		3.5	2.75	22,600	15,450		7,180	7,000	27,200
3/24		4.0	2.7	22,950	15,910		7,140	7,130	26,200
3/30		4.6	2.68	25,100	16,800		7,330	7,170	27,580
4/2		4.3	2.75	25,300	15,550		7,680	7,350	28,400
4/7		3.8	2.8	23,150	16,050		7,550	7,430	27,600
4/12		3.2	2.8	25,200	18,500		7,430	7,260	28,600
4/14		3.3	3.4	23,900	13,450		7,250	7,050	18,600
4/16		3.2	2.7	24,700	19,150		6,930	6,900	26,600
4/21		3	2.75	22,050	16,800		6,680	6,600	25,100
4/23		1.9	2.8	21,200	14,600		6,720	6,620	23,600
		3.0	2.6	22,300	19,050		6,503	6,430	24,800
4/30		3.0	2.7	23,000	18,600		6,760	6,380	25,400
5/5		3.0	2.85	23,250	16,600		6,930	6,590	25,050
5/11		3.3	2.30	20,700	15,650		6,150	6,000	24,300
5/19		3.0	3.3	21,000	15,950		6,340	6,120	24,000
5/25		3.0		21,180	17,620		6,150	5,950	

FLOW POINT NO. 3

Date 1970	Time	Flow GPM	pH	Net Acidity mg/1	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/1	Total Iron mg/1	Ferrous Iron mg/1	Sulfate mg/1
6/8		2.7		19,700	16,100		5,590	5,400	21,000
6/15		3.3	2.55	19,350	16,800		5,790	5,600	21,200
6/22		3.2	2.85	18,600	15,250		5,450	5,310	21,000
6/25		2.8	2.7	18,000	15,000		5,300	5,200	20,750
7/1		2.6	2.8	17,700	17,400		5,260	5,040	20,100
7/6		2.2	2.9	17,600	15,110		5,250	5,035	20,200
7/13		1.8	2.9	17,500	16,600		5,090	5,040	19,700
7/17		1.6	2.7	17,900	13,500		5,150	5,040	19,600
7/21		1.5	2.85	21,000	13,600		5,250	5,090	19,200
7/24		1.4	2.9	17,500	13,800		5,200	5,040	19,900

FLOW POINT NO. 5

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
4/17			2.4			0	8,340	7,625	32,928
7/30		0.43	2.4	22,000	23,500	0	7,620	7,250	
8/4		0.46	2.35	21,450	22,400	0	7,560	7,080	
8/6		0.46		21,500		0	7,500	6,950	
8/12		0.38	2.4	20,750	22,050	0	7,500	7,180	
8/14			2.4	20,900	23,900	0	7,360	7,050	
8/19			2.45	21,400	24,100	0	7,590	7,260	
8/21		0.38	2.45	21,750	22,100	0	7,560	7,025	
8/25		0.38	2.5	20,400	22,400	0	7,530	7,025	
8/28		0.38	2.45	20,150	22,400	0	7,310	7,000	
9/3		0.39	2.1	22,000	21,250	0	7,220	5,860	
9/4	09:40	0.48	2.35	23,000	22,200	0	7,225	6,650	
9/10		0.35	2.5	20,250	19,600	0	7,080	6,825	
9/12		0.32	2.5	20,150	22,550	0	7,230	6,900	
9/16		0.33	2.60		21,300				
9/18		0.34			19,300				
9/29		0.33	3.1	19,500	19,300	0	7,050	6,800	
10/2		0.34	2.6	20,150	18,800	0	7,020	6,750	
10/6		0.45	2.5	19,150	20,450	0	6,900	6,590	
10/9		0.31	2.7	20,000	19,300	0	6,770	6,720	
10/13		0.75	2.3	17,050	15,350	0	5,300	4,520	
10/15			2.45	19,900	15,230	0	6,950	6,740	24,480
10/20		0.33	2.75	19,295	17,450	0	6,920	6,610	24,300
10/27		0.33	2.7	19,200	16,100	0	6,820	6,590	24,000
11/4		0.31	2.6	19,500	14,620	0	6,750	6,530	24.000
11/11		0.31	2.5	20,000	14,400	0	6,660	6,380	10,550
11/14		0.34	2.8	18,700	12,520		6,640	6,260	10,560
11/18			2.2	9,300	14,000		6,120	5,440	11,100
11/21		0.39			13,000		6,975	6,060	4,530
11/25		0.32	3.47		13,650		6,410	6,295	23,500
12/5		0.48	3.54	18,550	11,790		6,270	6,100	19,650
12/9		0.38		18,800	11,410		6,240	6,050	20,100
12/12		0.37		18,800	10,192		6,120	5,930	10,080
12/16				19,100	13,320		6,250	5,910	10,500
12/19		0.34		17,775	11,650		6,100	5,940	20,100
12/23				19,100	9,400		6,000	5,700	10,350
1970									
1/5		0.44	2.3	18,800	13,000		5,875	5,450	19,950
1/14		0.03	2.6	18,400	14,100		5,675	5,300	19,850
1/16		0.09	2.55	18,850	12,540		5,555	5,170	18,330
1/26		0.48	2.4	18,300	11,420		5,500	5,140	19,500
1/28		0.55	2.5	18,350	14,680		5,000	4,380	20,100
2/2		0.48	2.3	16,900	9,520		4,787	4,250	9,900
2/5		0.88	2.35	15,850	10,850		4,270	3,500	17,900
2/9		0.53	2.3	19,700	12,210		5,320	4,470	18,630
2/13		0.46	2.5	20,000	15,250		5,920	5,499	20,255
2/17		1.4	2.55	14,400	9,630		3,360	2,520	15,350
2/20		0.40	2.5	19,800	12,100		6,150	5,520	20,110
2/25		0.37	2.6	21,400	11,230		6,340	5,950	24,850
2/27		0.37	2.55	21,550	15,600		6,530	6,080	19,000
3/3		1.1	2.3	21,550	14,550		5,270	3,745	19,700
3/6		0.88	2.3	23,325	15,800		6,440	5,500	27,200
3/8		0.67							
3/10		0.63	2.45	25,500	15,100		7,250	6,550	20,100
3/13		0.8	2.5	25,250	14,650		7,050	6,440	24,200
3/20		0.88	2.5	24,900	14,550		7,300	6,550	28,200
3/24		0.68	2.45	23,400	16,800		7,540	6,880	28,000
3/30		0.65	2.4	24,300	16,352		7,425	6,850	27,580
4/2		0.71	2.55	25,000	15,450		7,650	7,000	28,400
4/7		0.71	2.55	24,100	16,600		7,770	7,320	27,200
4/12		0.65	2.5	24,900	19,050		7,790	7,350	28,400
4/14		0.72	3.2	25,000	14,450		7,820	7,520	17,500
4/16		0.63	2.4	24,800	20,400		7,800	7,560	28,600
4/21		7.2	2.45	25,250	18,592		7,600	7,100	27,600
4/23		0.66	2.5	24,800	15,700		7,600	7,290	21,900
4/28		0.68	2.35	24,800	20,040		7,390	6,930	26,885
4/30		0.72	2.45	24,600	22,250		7,650	7,100	27,100
5/5		0.60	2.55	24,500	19,300		7,640	7,300	26,800
5/11		0.92	2.45	24,800	17,625		6,725	6,150	26,200
5/19		0.36	3.25	25,000	19,320		7,760	7,230	26,400
5/25		0.47		23,500	21,150		7,790	7,300	

FLOW POINT NO. 5

Date 1970	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
6/8		0.49		25,700	19,600		7,550	6,910	26,800
6/15		0.49	2.15	23,800	20,750		7,490	6,950	20,200
6/22		0.45	2.5	23,800	19,500		7,490	7,050	26,700
6/25		0.43	2.35	23,300	20,190		7,380	7,000	26,500
7/1		0.38	2.4	23,200	23,000		7,490	7,060	27,700
7/6		0.44	2.5	23,300	20,180		7,500	6,940	26,000
7/13		0.36	2.5	23,300	20,850		7,210	6,900	25,300
7/17		0.34	2.4	22,800	17,700		7,260	7,050	25,430
7/21		0.32	2.5	23,000	17,100		7,260	6,900	24,950
7/24		0.38	2.5	22,000	17,000		7,100	6,700	24,300

FLOW POINT NO. 6

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
6/24	07:05		1.9		1,037	0	1,835	344	
7/2	04:45		1.15	41,500	37,000	0	10,845	3,242	
7/2	08:32		1.35	39,000	34,500		10,300	3,000	
7/2	08:43		1.25		35,700				
7/2	08:53		1.25	39,200	34,700		10,500	2,990	
7/2	09:00		1.25	35,630	31,700		9,480	2,470	
7/2	09:04		1.3		30,000				
7/2	09:09		1.25	35,350	31,400		9,160	2,325	
7/2	09:14		1.3		29,200				
7/2	09:17		1.3	30,750	28,000		8,090	1,825	
7/2	09:19		1.3	28,200	26,500		7,500	1,673	
7/2	09:22		1.3		24,600				
7/2	09:25		1.35	22,300	22,400		5,700	1,118	
7/2	09:28		1.4		21,300				
7/2	09:31		1.35		23,000				
7/2	09:33		1.35	19,325	23,300		5,300	1,395	
7/2	09:36		1.4	16,110	19,050		4,150	943	
7/2	09:40		1.5	13,600	16,800		3,460	760	
7/2	09:44		1.6	10,650	14,100		2,610	558	
7/2	09:47		1.7	6,850	10,300		1,680	344	
7/2	09:52		2.0	2,300	51,500		510	112	
7/2	09:58		2.0	2,250	51,500		503	110	
7/2	10:04		2.0	3,175	68,400		745	160	
7/2	10:13		1.95		87,500				
7/2	10:30		1.85	6,050	10,500		1,450	291	
7/2	10:47		1.75		11,300				
7/2	10:59		1.65		12,000				
7/2	11:18		1.6	9,950	13,300		2,550	492	
7/2	11:31		1.6		14,100				
7/2	11:45		1.55	11,675	14,800		3,020	626	
7/2	12:00		1.5		16,050				
7/2	12:30		1.45	15,500	19,300		4,000	867	
7/2	12:45		1.4		19,500				
7/2	13:05		1.4	18,150	20,800		4,700	1,085	
7/2	13:25		1.35		21,800				
7/2	13:45		1.35	20,000	22,800		5,140	1,270	
7/2	14:50		1.35		24,300				
7/2	15:35		1.4		23,800				
7/2	16:05		1.35	22,400	25,800		5,830	1,990	
7/2	16:40		1.35		26,400				
7/11	08:55		2.1	17,600	13,200	0	4,330	1,025	
7/11	08:57		1.9	18,400	14,000	0	5,050	1,150	
7/11	08:59		1.85	19,100	14,300	0	5,320	988	
7/11	09:00	467	1.8	18,700	14,500	0	5,300	1,005	
7/11	09:01	419	1.8	18,300	14,500	0	5,250	985	
7/11	09:02	206	1.8	17,800	14,500	0	5,180	839	
7/11	09:03		1.8	17,500	13,600	0	4,760	750	
7/11	09:04		1.8	17,000	13,600	0	4,670	733	
7/11	09:05		1.8	16,900	13,600	0	4,650	738	
7/11	09:07		1.8	16,700	13,800	0	4,630	750	
7/11	09:11		1.75	17,200	14,300	0	4,810	828	
7/11	09:14		1.75	18,300	14,800	0	4,940	884	
7/11	09:19		1.7	18,700	15,600	0	5,200	984	
7/11	09:23		1.7	19,400	16,100	0	5,400	1,050	
7/11	09:27		1.65	20,000	16,700	0	5,550	1,105	
7/11	09:33		1.65	20,900	17,500	0	5,750	1,160	
7/21	14:51	6.3			16,000		4,460	1,460	
7/21	14:52	390			13,500		4,130	940	
7/21	14:53	790			12,050		3,370	630	
7/21	14:54	1630			11,400		3,180	445	
7/21	14:55	3320			10,800		2,770	380	
7/21	14:56				10,100		2,480	331	
7/21	14:57				8,500		1,935	230	
7/21	15:00				6,710		1,230	136	
7/21	15:01				5,930		1,005	114	
7/21	15:02				5,490		861	93	
7/21	15:05				5,280		738	73	
7/21	15:07	2420			5,600		828	86	
7/21	15:08	1630			6,060		940	105	
7/21	15:10	1030			6,430		1,020	116	
7/21	15:15	480			7,150		1,180	136	
7/21	15:20	320			7,830		1,295	162	
7/21	15:25	176			8,520		1,495	190	

FLOW POINT NO. 6

Date 1969	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
7/21	15:30	196			8,700		1,510	197	
7/21	15:35	119			8,950		1,520	202	
7/21	15:40	33			9,420		1,630	243	
7/21	15:45	13			10,100		1,790	286	
7/21	15:50	3.6			10,800		1,990	352	
7/21	16:10				13,400		2,610	560	
7/22	09:23	36			9,470				
7/22	09:32	33			10,600				
7/22	09:51	6.3			13,100				
7/22	10:06	15			13,700				
7/22	11:10	2.2			16,100				
7/22	11:30	2.2			17,800				
7/22	12:15	15			16,500				
7/22	13:15	3.6			19,100				
7/22	13:45	2.2			21,000				
7/22	14:15	0.90			22,950				
7/22	14:45				24,300				
7/22	15:15				26,200				
7/22	15:45				27,900				
7/22	16:15				27,900				
7/22	16:45				28,100				
7/22	19:15				27,200				
7/22	20:50				27,600				
7/24	16:18			37,600	24,000		10,250	2,060	
7/24	16:22	0.90			23,000				
7/24	16:21	44		18,900	16,000		5,080	1,060	
7/24	16:26	419		14,750	13,900		3,960	715	
7/24	16:28	790		11,750	12,100		3,070	465	
7/24	16:31	907		7,925	9,340		1,990	246	
7/24	16:33	588		7,575	9,180		1,900	232	
7/24	16:39	320			9,610				
7/24	16:57	271		7,100	9,500		1,760	227	
7/24	17:05	44			10,920				
7/24	17:10	13		9,075	11,650		2,240	378	
7/24	17:30			11,730	14,670		3,030	765	
7/25	10:40			25,400	24,000		6,790	3,110	
7/26	08:30			12,500	15,250		3,170	2,640	
8/20	16:47		2.0	23,700	16,700		6,680	2,040	
8/20	16:48	237	2.0	23,750	16,700		7,030	1,825	
8/20	16:49	588	1.9	27,500	18,500		8,300	2,090	
8/20	16:52	348	2.05	22,750	16,000		6,600	1,235	
8/20	16:55	176	2.0	20,500	14,800		5,700	1,003	
8/20	17:00	119		19,100	14,550		5,380	962	
8/20	17:07	216	2.05		12,830		4,180	678	
8/20	17:12	624	2.1	10,900	10,400		2,910	478	
8/20	17:20	227		8,800	9,350		2,320	373	
8/20	17:35	13		11,700	11,750		3,150	682	
8/20	18:11	0.90	2.05	11,050	11,350		3,035	648	
10/13	12:25		1.95	8,400	8,460		1,995	326	8,930
12/11	08:50			18,050			6,490	534	10,630
12/11	10:30			25,456			6,920	950	19,680
1970									
2/5	14:00	10	1.7	10,420	9,300		2,560	581	11,080
2/5	14:20	48	1.7	9,850	9,300		2,410	537	10,750
2/5	15:40		1.7	9,050	7,400		2,230	469	9,880
2/5	16:30		1.75	9,480	7,250		2,560	492	10,750
2/7	08:40		2.0	16,900	11,650		4,360	570	16,850
2/7	09:05		1.9	18,530	12,550		4,850	649	17,850
2/17	14:30		1.95	6,150	5,820		1,540	356	6,240
2/17	15:00		1.95	5,920	5,210		1,430	257	5,930
2/17	16:00		1.95	6,130	5,150		1,495	257	6,340
2/17	17:00		1.9	7,600	5,940		1,485	356	7,820
2/17	18:00		1.9	10,000	7,390		2,440	413	9,550
2/18	09:30		1.75	13,650	11,760		3,520	603	14,130
2/18	10:10		1.7	14,250	12,100		3,620	660	14,620
2/18	12:20		1.6	20,775	17,992		5,170	1,073	19,050
2/22	12:30		1.9	12,300	8,960		3,190	537	10,000
2/22	13:20		2.0	12,625	9,630		3,190	493	10,280
2/22	14:00		2.0	11,400	9,410		2,905	425	9,880
2/22	14:40		2.0	14,175	10,300		3,590	514	14,950

FLOW POINT NO. 6

Date 1970	Time	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
3/2	08:30		1.6	21,500	17,350		5,310	604	
3/2	09:15		1.5	25,500	19,600		6,220	738	
3/2	10:15		1.5	28,000	20,830		6,580	817	
3/2	11:15		1.5	29,500	24,000		7,250	939	
3/2	13:00		1.5	32,000	25,200		7,730	1,140	
3/2	14:00		1.4	32,300	25,500		7,920	1,185	
3/2	15:00		1.4	32,700	26,000			1,262	
3/2	16:00		1.4	34,000	26,100			1,319	
3/3	08:40		1.5	31,500	21,950		7,800	1,375	33,600
3/3	09:00		2.0	9,250	9,300		2,145	359	9,650
3/4	09:15		1.7	11,000	9,300		2,527	436	
3/4	10:00		1.5	21,000	15,560		5,142	872	
3/4	11:30		1.9	10,500	8,850		2,482	413	
3/4	13:00		1.35	24,000	18,050		6,440	1,039	
3/4	16:10		1.25	30,000	20,750		7,435	1,253	
3/18	09:30	3.3	1.7	15,500	12,300		5,120	972	20,100
3/18	14:00		1.9	8,500	6,540		2,050	268	8,630
3/18	16:30		1.75	10,750	8,300		2,650	379	10,700
3/19	11:00		1.7	16,000	11,910		3,980	682	15,810
3/19	15:00		1.45	19,700	14,900		4,950	926	20,100
3/25	08:20		1.75	12,900	10,350		3,350	610	13,850
3/25	11:15		1.6	21,000	15,800		5,460	1,015	25,200
3/25	13:30		1.4	24,400	18,850		6,250	1,230	22,200
3/25	15:30		1.35	26,000	19,900		6,790	1,350	27,300
4/1	16:15		2.0	8,080	8,070		2,010	380	8,500
4/19	14:00		1.9	8,400	9,080		1,965	313	8,550
4/19	16:45		1.6	22,800	18,150		5,340	1,072	23,300
5/25	15:15			29,900	16,350		7,830	1,518	27,930
6/2	14:10			14,000	13,700		3,600	760	14,980
6/2	14:40			6,400	7,950		1,295	224	6,340
6/2	15:00			2,600	4,490		469	89	2,590
6/2	15:20			3,200	5,500		671	156	3,555
6/2	15:40			5,400	7,400		1,139	279	5,660
6/2	16:00			6,600	8,580		1,430	369	6,820
6/2	16:20			7,500	9,640		1,690	537	7,970
6/3	08:50			8,900	8,630		2,460	2,320	
6/3	09:30			2,600	4,370		536	151	3,745
6/3	10:15			5,500	7,100		1,280	364	
6/3	10:45			7,900	8,740		1,840	470	
6/3	11:30			10,800	10,620		2,560	632	11,520
6/3	13:00			2,700	4,250		497	83	
6/3	14:30			13,000	11,650		2,680	458	12,400
6/3	16:00			17,500	16,600		4,230	838	21,000
6/19	10:30		1.55	31,300	19,900		8,780	1,855	31,250
6/19	10:45		1.5	34,000	21,300		9,730	2,100	34,900
6/19	11:05	2.0	1.4	38,000	23,500		10,720	2,300	37,800
6/19	11:45		1.8	15,100	11,890		3,690	560	14,400
7/3	08:15		2.0	16,900	11,200		4,640	615	16,320
7/3	08:25		1.9	16,600	11,500		4,420	670	16,550
7/3	08:30		1.9	15,500	11,500		4,190	559	15,680
7/3	08:40		1.8	18,100	12,800		4 800	670	18,350
7/3	08:55		1.75	21,400	14,550		5,430	950	20,200
7/3	09:00		1.7	20,300	15,250		5,750	1,060	20,350
7/19	13:40		1.7	16,650	10,700		4,590	1,175	18,050
7/19	14:15		1.7	17,050	10,650		4,420	1,340	17,180

WALKER CREEK - UPSTREAM

Date 1969	Flow GPM	pH	Net Acidity[1] mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
2/27		6.45	70		120		Trace	840
3/4		7.2	-60		260	50	0	1,368
7/21			-15	840	40	0	0	
8/6					150	9	2	
8/14		7.4		1,735	160	Trace		
8/19		7.4		1,640	218	0	0	
8/21		7.4		1,435	200	5	0	
8/25		7.3		1,545	210	5.6	0	
8/28		7.3	-190	1,670	220	0.9	0	523
10/13		6.15	20	1,090	30	0	0	
11/14		8.5		1,130	110			1,058
11/18		5.3		1,280	5			
11/25		7.46	-15	1,420	100			
12/5		7.76	-20	1,265	110			
12/9			-30	997	120			786
12/12			-100	1,008	235			
12/16			-10	1,350	90			
12/19			-30	1,435	105			
12/23			-10	1,042	85			
1970								
1/5		6.2	-10	1,510	120			
1/26		5.9	30	266	40			
1/28		6.25	-10	870	70			
2/2		6.4	0	340	80			431
2/5		4.25	115	985	20			576
2/9		8.8	-50	426	50			432
2/13		5.9	80	1,041	45			528
2/17		5.3	50	985	30			552
2/20		6.0	-10	532	50			240
2/25		7.0	0	773				483
2/27		6.4	0	1,100				480
3/3		6.3	-20	226				82
3/6		5.8	-10	481				
3/10		6.3	-35	985				
3/13		6.3	-25	1,075				
3/20		7.0	-10	420				
3/24		6.6	-60	784				
3/30		6.65	-10	812				
4/2		6.65	-10	550				
4/7		6.6	-500	1,110				
4/12		6.9	-100	1,580				768
4/14		6.0	-10	763		13	12	5,760
4/16		7.1	-550	1,200				
4/21		7.0	-45	588				
4/23		6.0	-40	880				384
4/28		6.4	0	683				
4/30		6.6	-10	1,075				
5/5		6.8	-40	1,142				
5/11		7.0	-50	1,241		53	53	576
5/19		6.9	-50	1,245				
5/25			-50	1,680		0	0	
6/8			-30	1,020				288
6/15		6.7	-30	1,500		89	0	576
6/22		8.0	-60	1,590				960
6/25		7.5	-50	1,735				768
7/1		7.8	-20	2,380				
7/6		4.5	150	1,795				
7/13		4.2	190	1,995				1,155

(1) Minus net acidity values denote alkalinity

WALKER CREEK - DOWNSTREAM

Date 1969	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
7/30		2.8	7,050	9,900	0			
8/6			12,600		0	3,830	3,275	
8/14		2.5	17,250	19,150	0	5,060	4,990	
8/19		2.4	11,750	15,050	0	3,510	2,970	
8/21	6.0	2.45	11,800	12,750	0	3,235	2,240	
8/25	4.0	2.45	15,150	15,600	0	4,420	3,780	
8/28	1.8	2.4	17,000	18,140	0	5,060	4,780	
9/3	3.0	2.05	16,900	17,750	0	5,180	4,700	
9/4	12	2.45	4,850	7,370	0	1,148	655	
9/10	3.0	2.5	11,900	13,800	0	3,510	3,085	
9/12	3.0	2.5	12,200	13,550	0	3,655	3,175	
9/16	2.4	2.40		16,300				
9/18	4.0			7,960				
9/29	3.0	2.4	15,650	14,800	0	4,650	4,090	
10/13		2.5	6,600	7,400	0	1,775	1,500	
10/27		2.5	14,900	12,900	0	4,430	3,980	18,300
11/4		2.6	12,500	9,500	0	3,350	2,930	14,400
11/11		2.45	15,600	11,700	0	4,500	3,550	10,680
11/14		2.32	16,400	10,080		5,030	4,260	10,760
11/18	180	2.15	4,900	4,870		993	493	5,520
11/21		2.4		6,370		1,810	1,420	3,475
11/25		3.38		6,210		1,520	1,062	7,700
12/5		3.44	8,450	5,940		2,160	1,675	9,990
12/9			5,770	4,490		1,350	1,050	6,620
12/12			5,025	3,808		1,170	860	6,000
12/16			5,800	5,480		1,450	1,100	6,820
12/19			7,113	6,160		1,585	1,451	8,880
12/23			7,650	4,940		1,885	1,473	8,650
1970								
1/5		2.4	5,700	5,210		1,250	950	6,240
1/26		2.65	3,500	3,360		939	738	4,120
1/28		3.1	1,201	2,420		279	223	1,610
2/2		3.4	500	874		118	105	816
2/5		2.95	2,900	3,220		525	413	2,830
2/9		3.0	1,400	1,960		355	268	1,726
2/13		3.0	2,900	3,360		592	537	3,120
2/17		2.9	2,500	3,050		604	536	3,190
2/20		2.7	4,500	4,480		1,272	1,117	5,810
2/25		2.85	4,800	4,370		126	114	5,310
2/27		2.9	3,850	4,700		938	849	4,420
3/3		3.35	515	1,345		115	105	625
3/6		3.0	4,250	4,930		1,015	962	5,430
3/10		3.0	5,750	5,770		1,655	1,475	7,250
3/13		2.8	4,750	5,040		1,250	1,062	5,550
3/20		3.0	3,120	3,360		889	760	3,840
3/24		2.7	4,200	4,940		1,140	1,040	4,420
3/30		2.65	18,200	8,400		2,439	2,230	19,750
4/2		2.75	5,300	5,370		1,385	1,160	6,380
4/7	18	2.9	4,500	4,760		1,275	1,140	5,425
4/12	25	2.7	5,450	6,830		1,340	1,162	6,390
4/14	80	2.9	7,800	3,800		730	615	3,696
4/16	48	2.6	4,800	6,730		1,229	1,115	5,855
4/21	150	3.15	1,650	2,604		430	347	2,136
4/23	48	2.8	3,630	4,300		895	816	4,325
4/28		3.2	683	1,558		115	89	816
4/30	50	2.6	4,400	6,620		1,118	783	5,280
5/5		2.75	5,250	6,220		1,342	1,162	6,100
5/11		3.1	6,500					
5/19		3.15	10,600	11,200		2,905	2,525	888
5/23	11							13,630
5/25	4.3							16,270
6/8	3.2		6,500	7,400		1,510	1,312	6,920
6/15	8.0	2.25	9,950	11,500		2,550	2,080	11,300
6/22	4.2	2.5	11,300	11,420		3,200	2,600	13,350
6/25	5.7	2.2	12,800	13,320		3,240	2,630	14,500
7/1	2.4	2.6	18,800	18,150		5,310	4,810	21,600
7/6	2.4	2.45	20,000	16,150		5,310	4,750	20,900
7/13	6.0	2.4	21,000	18,600		5,700	5,090	22,850
7/17	0.58	2.25	21,400	16,500		5,930	5,370	23,550
7/24	0.11	2.4	19,400	15,000		5,400	4,750	22,100

WALKER CREEK - UNDER ILLINOIS RTE 127[1]

Date 1969	Flow GPM	pH	Net Acidity[2] mg/l	Conductivity Microrhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
11/18		3.1		1,860		36	6.7	1,776
11/25		3.49		2,580		625	335	2,090
12/5		3.56	1,625	2,900		203	43	2,420
12/9			4,920	2,550		350	170	2,552
12/12			1,050	1,613		158	54	1,585
12/16			1,550	1,965		230	54	2,400
12/19			1,550	2,005		230	54	2,400
12/23			300	2,050		58	34	625
1970								
1/26		4.5	130	504	20	11	10	528
2/2		3.4	400	1,187		78	69	672
2/5		4.9		1,365		35	35	960
2/9		5.1	195	627	35			240
2/13		4.9	260	1,108	25			768
2/17		4.5	340	1,231	30			671
2/25		4.4	290	997				485
3/3		5.9	-60	360				144
3/6		5.1	180	761				264
3/10		3.5	550	1,355		67	67	1,200
3/13		3.7	600	2,130		78	67	1,320
3/20		5.0	155	570		207	157	
3/24		4.45	250	1,030		84	81	745
3/30		5.0	+48	1,187		604	553	2,020
4/2		5.1	290	907				576
4/7		3.6	450	1,815		38	30	576
4/12		3.3	500	1,710		36	22	1,200
4/14		4.4	290	10,650		35	27	968
4/21		5.0	150	1,020				552
4/28		2.1	900	1,792		156	112	1,008
4/30		4.5	140	1,200				576
5/11		4.5		616		6.7	6.7	432
5/19		3.4	340	1,735		8.9	2.2	12,380
5/25			-160	1,725		0	0	
6/8			-180	1,430		0	0	1,008
6/22		6.35	-50	2,420		13	2.2	1,500
7/1		2.6	1,600	4,600		161	17	2,690
7/6		2.5	2,600	4,880		436	22	3,840
7/13		3.1	3,800	6,270		548	5.6	4,990
7/17		2.25	4,200	5,100		615	391	5,330
7/21		2.4	3,700	4,900		486	5.6	4,700
7/24		2.35	4,450	5,200		615	20	5,750

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(1) Approximately 3 miles from site.

(2) Minus net acidity values denote alkalinity.

APPENDIX XI-E

SEEPAGE FLOW AND WATER QUALITY DATA

SPRING NO. 1

Date 1969	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
5/7		3.1	45,000		0	9,744	9,727	42,460

SPRING NO. 3

1969								
5/7		2.9	15,150		0	6,753	6,697	21,216
5/28			20,000	19,900	0	6,663	6,440	21,936
7/21			16,650	21,300		6,280	5,820	

SPRING NO. 5

1969								
7/8		2.4	15,200	16,600	0	2,996	2,688	
7/17		2.3	9,750	20,700	0	5,880	5,170	
7/30	0.27	2.55	18,850	19,900	0	5,570	4,780	
8/4	0.22	2.4	20,200	20,400	0	6,255	5,560	
8/6	0.22		20,350		0	6,320	5,590	
8/12	0.14	2.3	21,500	22,050	0	6,750	6,200	
8/14		2.4	21,050	23,400	0	6,350	5,750	
8/19		2.55	19,600	23,200	0	6,650	6,140	
8/21	0.14	2.65	20,100	19,900	0	6,290	5,530	
8/25	0.13	2.6	20,250	20,650	0	6,190	5,510	
8/28	0.13	2.5	19,750	22,180	0	6,150	5,590	
9/3	0.15	2.2	18,450	19,750	0	5,880	5,350	
9/4	0.20	2.40	20,400	20,050	0	5,770	5,220	
9/10	0.20	2.7	17,300	17,150	0	5,670	5,270	
9/12	0.17	2.55	18,500	21,700	0	6,000	5,580	
9/16	0.10	2.70		19,450				
9/18	0.10			16,800				
9/29	0.13	2.7	17,000	17,100	0	5,260	4,900	
10/2	0.14	2.65	17,500	15,900	0	5,230	4,810	
10/6	0.09	2.55	16,850	18,200	0	5,210	4,830	
10/9	0.10	2.85	15,700	16,800	0	5,070	4,780	
10/13	0.80	2.3	10,000	9,750	0	1,905	1,242	
10/15		2.75	14,450	11,650	0	4,550	4,470	19,000
10/20	0.19	2.9	14,150	14,000	0	4,460	4,180	18,210
10/27	0.15	2.95	13,125	12,550	0	4,220	3,980	15,900
11/4	0.16	2.8	13,000	10,800	0	4,050	3,810	16,300
11/11	0.14	2.7	12,250	10,800	0	3,930	3,580	10,750
11/14	0.06	3.15	11,200	7,500	0	3,640	3,510	10,310
11/18		2.4	13,700	10,000		3,480	3,090	11,330
11/21	0.14	2.75		9,970		3,810	3,650	4,440
11/25	0.07	3.45		11,150		3,730	3,500	15,650
12/5	0.41	3.57	11,150	8,120		3,420	3,260	14,000
12/9	0.12		11,050	7,620		3,420	3,280	9,850
12/12	0.09		11,000	7,450		3,443	3,390	10,210
12/16			5,300	9,300		3,100	2,910	10,600
1970								
1/26	0.24	2.65	9,350	7,500		2,800	2,720	9,640
1/28	0.23	2.85	9,750	9,410		2,370	2,270	10,850
2/2								
2/5	0.81	2.8	4,500	5,150		1,210	1,105	6,000
2/9	0.23	2.7	8,630	7,615		2,415	2,328	9,410
2/13	<0.01	2.9	9,075	9,520		2,755	2,498	9,670
2/17	1.0	2.8	4,150	4,310		1,005	894	5,250
2/20	0.25	2.8	8,000	9,700		2,660	2,550	7,730
2/25	0.12	2.95	11,430	8,000		3,110	2,980	12,750
2/27	0.11	2.7	10,400	11,000		3,175	3,080	9,700
3/3	0.36	2.8	9,300	9,410		2,500	2,310	9,800
3/6	0.27	2.9	10,950	10,300		3,165	3,01[illegible]	13,630
3/8	0.16							
3/10	0.21	2.85	12,750	10,400		3,840	3,480	9,750
3/13	0.27	3.1	10,750	9,180		3,090	2,860	8,900
3/20	0.25	2.85	12,400	9,860		3,680	3,410	15,100

SPRING NO. 5 (cont'd)

Date 1970	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
3/24	0.23	2.65	13,100	12,200		4,100	3,700	16,590
3/30	0.25	2.7	14,700	11,402		4,370	3,880	17,280
4/2	0.18	2.8	16,000	12,310		4,980	4,430	19,400
4/7	0.21	2.8	15,450	12,330		4,850	4,360	18,600
4/12	0.167	2.65	18,200	15,350		5,340	4,810	20,900
4/14	0.23	3.4	16,200	10,200		5,033	4,740	8,350
4/16	0.16	2.5	17,800	16,600		5,250	4,910	20,700
4/21	0.17	2.70	17,200	14,550		5,200	5,025	20,600
4/23	0.20	2.8	16,800	12,550		5,190	4,820	19,300
4/28	0.21	2.5	16,000	16,700		4,980	4,790	20,550
4/30	0.13	2.7	17,900	18,600		5,590	5,200	21,400
5/5	0.17	2.75	18,000	16,250		5,430	5,300	20,650
5/11	0.24	2.6	17,100	14,325		4,950	4,660	19,300
5/19	0.16	3.15	18,000	16,800		5,480	5,140	20,200
5/25	0.10		19,000	18,500		5,780	5,460	
6/8	0.09		18,000	16,500		5,250	4,840	20,400
6/15	0.11	2.4	17,350	18,850		5,460	5,140	19,600
6/22	0.08	2.65	17,700	16,800		5,650	5,250	21,000
6/25	0.11	2.5	16,800	17,650		5,300	5,090	20,190
7/1	0.10	2.6	17,400	21,300		5,480	5,090	20,850
7/6	0.11	2.6	16,900	16,150		5,250	4,700	19,200
7/13	0.09	2.6	16,200	17,400		4,800	4,530	18,950
7/21	0.06	2.6	17,000	15,200		5,140	4,870	20,550
7/24	0.07	2.6	15,800	14,500		4,800	4,430	19,500

SPRING NO. 6

1970								
4/12	0.83	5.6	4,200	6,150		2,200	2,190	7,000

SPRING NO. 7

1969								
5/7		2.0	33,250		0	15,473	14,802	53,760
1970								
2/13	1.6	2.6	19,275	19,910		8,643	8,313	28,945
2/17	1.4	2.2	39,800	12,310		6,240	5,350	19,380
2/20	1.2	2.35	26,900	16,800		9,550	9,030	20,230
2/25	0.76	2.5	24,800	16,250		9,550	9,200	30,250
2/27	0.57	2.4	30,550	20,080		9,840	9,448	26,350
3/3	1.6	2.3	29,650	20,300		9,360	7,930	22,580
3/6	2.4	2.25	30,875	20,700		10,010	9,330	30,000
3/8	2.2							
3/10	1.3	2.4	32,000	20,200		10,950	10,850	29,900
3/13	0.81	2.3	32,750	19,050		10,550	9,930	26,600
3/20	1.5	2.45	29,600	18,600		10,500	9,800	35,100
3/24	1.5	2.4	29,100	20,400		9,850	9,400	33,200
3/30	1.5	2.31	30,000	19,880		9,880	9,300	33,400
4/2	1.1	2.45	31,500	18,800		10,400	9,700	36,000
4/7	0.70	2.4	31,050	15,700		10,500	9,390	32,600
4/12	0.28	2.25	35,700	24,100		11,350	10,700	42,700
4/14	0.27	3.0	34,900	18,050		11,250	10,040	18,900
4/16	0.14	2.1	38,000	28,000		12,200	11,450	43,200
4/21	0.41	2.35	32,450	23,800		10,100	10,050	39,250
4/23	0.38	2.3	34,350	20,400		11,320	10,540	22,000
4/28	0.13	2.1	35,900	29,100		11,950	11,480	41,400
4/30	0.09	2.2	39,300	32,000		12,750	11,720	44,900
5/5	0.12	2.2	35,900	28,000		12,650	11,550	42,700
5/11	0.13	2.1	37,000	24,640		11,480	10,050	37,000
5/19	0.03	2.5	47,000	31,180		14,850	13,950	50,300

SPRING NO. 8

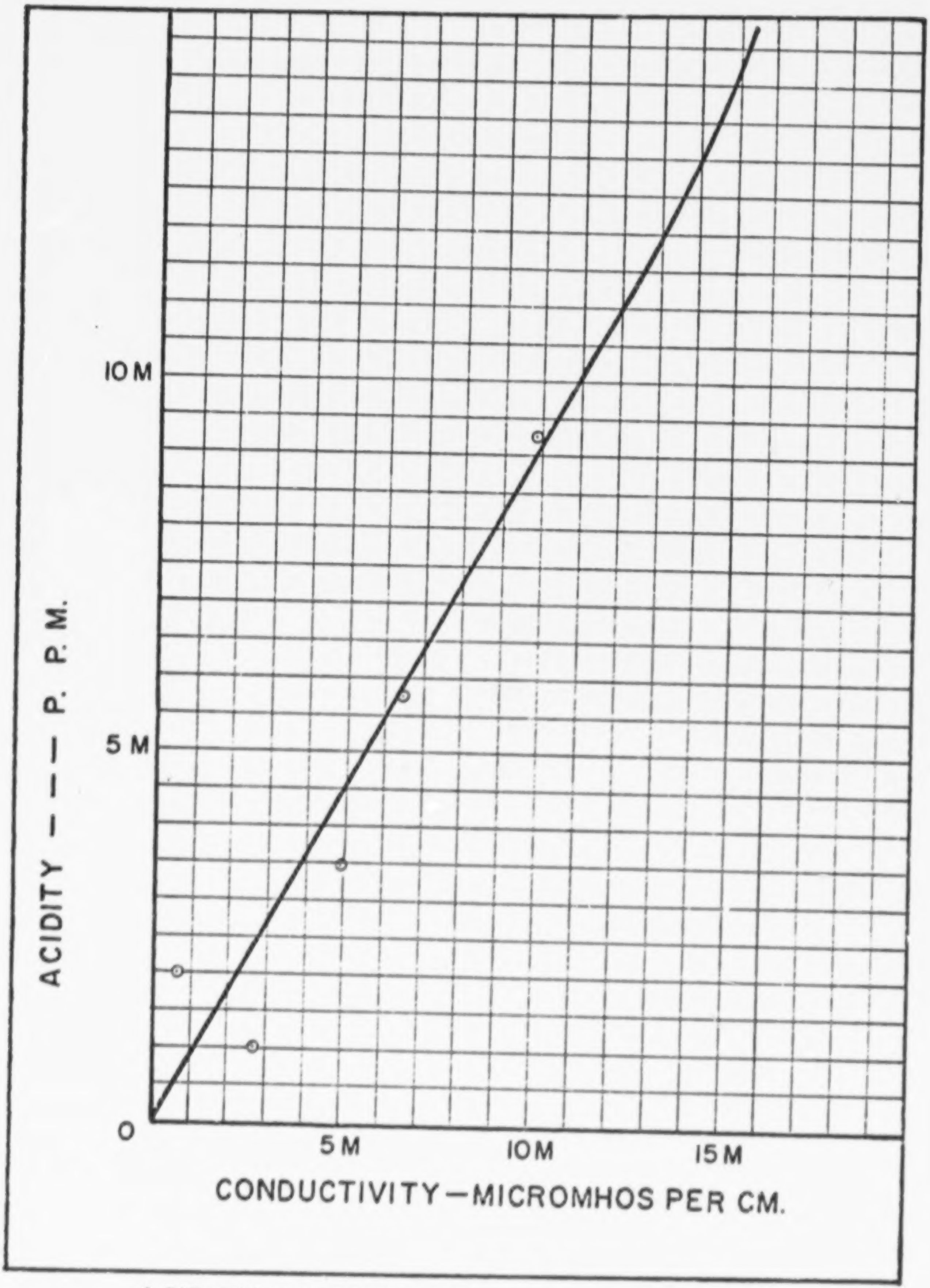
Date 1970	Flow GPM	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Alkalinity Methyl Orange mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
3/6	0.84	2.0	24,850	20,600		7,120	5,580	27,850
3/8	0.78							
3/10	0.80	2.2	25,700	17,350		8,150	7,100	28,100
3/13	0.86	2.15	24,000	15,250		7,500	6,440	21,100
3/20	1.0	2.45	20,850	14,800		7,130	6,450	23,600
3/24	0.60	2.3	20,350	16,900		7,190	6,710	24,850
3/30	1.3	2.25	23,900	17,248		7,850	7,200	26,400
4/2	0.86	2.5	21,700	15,550		7,460	7,010	24,850
4/7	0.80	2.5	20,700	20,190		7,075	6,950	23,700
4/12	1.5	2.5	25,500	18,500		7,170	6,860	25,800
4/14	0.53	3.1	19,200	13,220		6,950	6,520	13,950
4/16	0.36	2.3	21,600	20,050		7,000	6,780	22,800
4/21	0.37	2.3	19,450	17,920		6,790	6,460	23,800
4/23	0.39	2.4	20,500	15,500		6,970	6,490	20,650
4/28	0.28	2.1	20,800	21,190		6,760	6,320	24,400
4/30	0.17	2.3	22,000	22,650		7,450	6,830	26,000
5/5	0.20	2.5	20,500	19,050		6,900	6,600	23,300
5/11	0 29	2.2	18,300	16,640		5,900	5,400	20,400
5/19	0.11	2.85	21,000	19,600		6,750	6,230	23,040
6/8	0.16		19,100	17,900		5,950	5,420	20,900
6/15	0.78	2.1	18,400	20,100		6,180	5,920	20,900
6/22	0.15	2.4	18,600	18,400		6,430	6,180	22,200
6/25	0.16	2.2	18,100	19,600		6,260	6,050	21,600
7/6	0.15	2.4	16,200	16,800		5,760	5,200	20,200

SPRING NO. 9

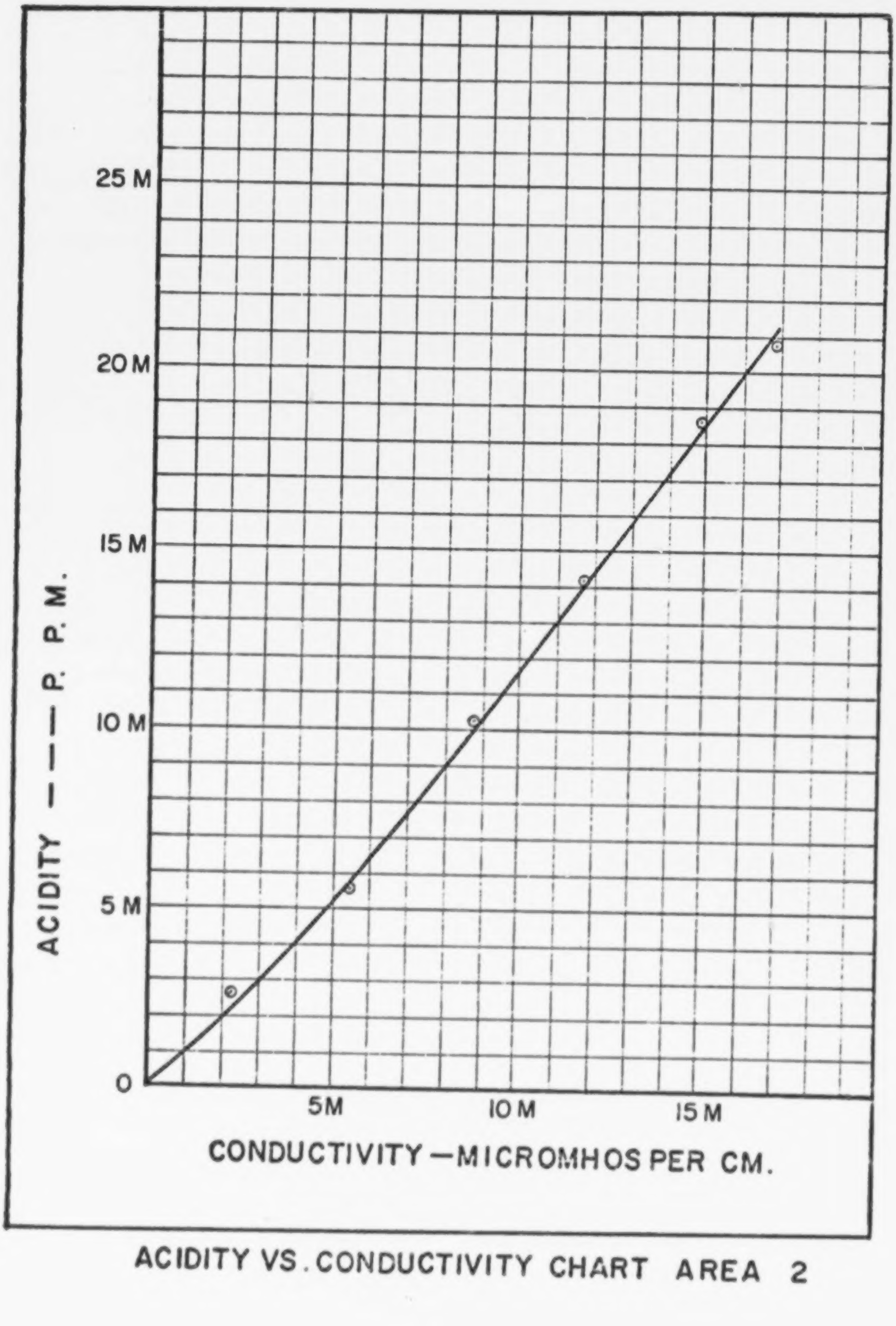
1969								
7/30	0.43	2.5	23,000	23,200	0	7,700	7,210	
8/4	0.30	2.5	22,400	22,100	0	7,350	6,920	
8/6	0.27		22,650		0	7,230	6,710	
8/12	0.19	2.5	22,100	22,050	0	7,090	6,850	
8/14		2.45	21,600	24,100	0	7,040	6,650	
8/19		2.35	10,850	12,700	0	3,170	1,590	
8/21	0.20	2.6	20,400	20,700	0	6,770	6,250	
8/25	0.13	2.6	20,400	21,050	0	6,490	6,120	
8/28	0.11	2.5	19,500	22,230	0	6,575	6,150	
9/3	0.11	1.15	19,250	20,400	0	6,360	6,020	
9/4	0.16	2.30	18,650	19,050	0	5,210	4,670	
9/10	0.18	2.6	17,500	17,400	0	5,870	5,560	
9/12	0.17	2.5	18,775	20,900	0	5,920	5,530	
9/16		2.60		19,800				
9/18	0.10			16,800				
9/29	0.09	2.7	15,600	16,550	0	5,120	4,910	
10/2	0.09	2.65	16,750	15,800	0	5,160	4,890	
10/6	0.05	2.5	16,500	18,600	0	5,390	5,060	
10/9	0.06	2.7	15,800	16,300	0	5,030	4,810	
10/13	0.37	2.3	12,750	12,320	0	3,270	2,635	
10/15		2.55	14,450	11,370	0	4,780	4,540	18,750
10/20	0.10	2.8	14,145	14,100	0	4,490	4,340	18,400
10/27		2.5	14,900	12,900	0	4,430	3,980	18,300
11/4	0.04	2.69	14,000	11,100	0	4,250	4,060	16,800
11/11	0.05	2.6	13,000	11,200	0	3,990	3,840	10,520
11/18		2.0	15,400	11,550		3,740	2,860	11,040
11/21	0.06	2.5		10,480		3,910	3,560	4,440
12/16			12,000	9,850		3,440	2,925	10,530
1970								
1/26	0.07	2.3	9,600	7,050		2,380	1,875	9,780
1/28	<0.01	2.45	10,750	10,580		2,620	2,060	12,950
2/5	0.04	2.3	9,170	6,330		1,765	704	10,950
2/17	0.32	2.35	7,050	5,330		1,685	1,072	8,190
3/3	0.12	2.25	10,000	9,350		2,480	1,775	11,350
3/6	0.13	2.2	14,800	11,985		3,890	2,895	17,050
3/20	0.11	2.4	12,700	10,050		3,800	2,970	15,810
3/30	0.14	2.3	13,550	13,332		5,170	4,625	20,200
4/2	0.09	2.35	18,400	13,335		5,380	4,620	20,700
4/12	0.07	2.3	20,700	17,100		5,940	5,300	23,700

APPENDIX XI-F

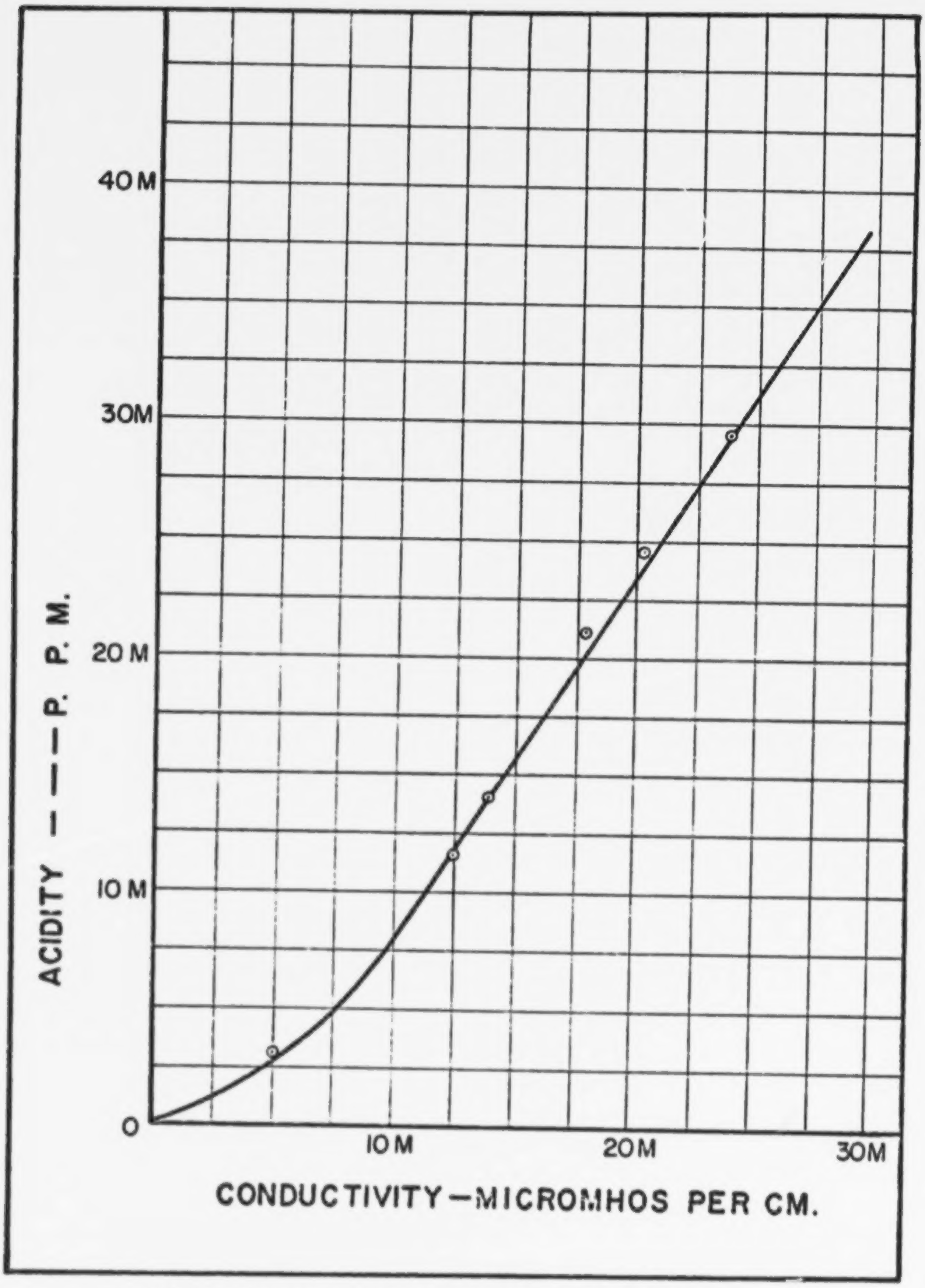
ACIDITY VS. CONDUCTIVITY CHARTS



ACIDITY VS. CONDUCTIVITY CHART AREA I



ACIDITY VS. CONDUCTIVITY CHART AREA 2



ACIDITY VS. CONDUCTIVITY CHART AREA 6

APPENDIX XI-G

OBSERVATION WELL DATA

OBSERVATION WELL DATA

Well No.	Elevation Top of Well ft.	11/29/68	12/7/68	1/13/69	1/24/69
1	486.99			445.42	
2	495.55			474.02	
3	481.45			451.74	451.72
4	468.07			439.84	
5	474.50			438.25	
6	474.33			439.70	
7	467.44			450.69	
8	486.98	449.74	447.05	446.55	449.96
9	496.39	448.88	449.00	449.42	450.26
10	494.06	458.10	457.81	457.89	457.89
12	477.14				
13	467.81				
14	473.02				
15	468.70				

OBSERVATION WELL DATA

Well No.	2/11/69	2/25/69	2/28/69	3/3/69	3/12/69
1	445.38	445.36	445.30	445.27	445.25
2	457.52	459.89			
3	452.60	452.63	452.67	452.44	452.28
4	442.05	442.22	441.34	442.17	442.01
5	441.50	439.96	440.35	440.83	441.19
6	440.33	440.35	440.35	440.33	440.31
7	451.48	451.23	451.32	451.23	450.90
8	447.80	443.78	443.80	443.97	443.22
9	449.88	450.52	454.00	451.23	449.73
10	459.22				
12					
13					
14					
15					

OBSERVATION WELL DATA

Well No.	3/17/69	4/1/69	4/9/69	4/15/69	5/26/69
1	445.25				
2					
3	452.05	451.86		451.76	451.95
4	441.86	441.97	449.13	444.59	442.28
5	441.19	441.12	441.12	441.08	441.38
6	440.27	440.20	440.25	440.31	440.25
7	451.03	450.94	450.94	450.98	450.90
8	443.24	443.25			443.23
9	449.67	449.50		449.38	449.68
10		444.39			
12					
13					
14					
15					

OBSERVATION WELL DATA

Well No.	6/11/69	6/26/69	7/3/69	7/10/69	7/17/69
1					
2					441.90
3	451.87	451.53	451.43	451.60	451.78
4	442.51	442.20	448.90	442.72	441.95
5	441.08	441.08	441.02	441.06	441.13
6	440.23	440.08	439.77	440.00	440.10
7	450.77	450.67	450.90	451.07	451.13
8	443.25				
9	449.56	449.41	449.29	449.27	449.43
10					443.10
12	443.22	447.16	449.31	449.12	448.14
13	441.52	441.66	441.87	441.85	441.79
14	440.64	440.62	440.87	441.46	441.69
15	438.87	438.83	438.87	438.80	438.78

OBSERVATION WELL DATA

Well No.	7/26/69	8/1/69	8/8/69	8/15/69	8/22/69
1		445.57	445.16		
2		441.90	441.82	441.78	441.72
3		452.08	452.28	452.20	452.08
4		442.40	442.37	442.30	442.16
5		441.18	441.21	441.19	441.21
6		440.14	440.13	440.02	440.05
7		451.37	451.36	451.23	451.15
8		442.87	442.81		
9		449.66	449.72	449.81	449.83
10		443.05	442.94	442.77	442.78
12		446.16	447.96	447.89	447.86
13		441.81	441.65	441.52	441.48
14		442.10	442.06	441.87	441.58
15		438.78	438.74	438.62	438.65

OBSERVATION WELL DATA

Well No.	8/30/69	9/6/69	9/15/69	10/9/69	11/22/69
1					
2	441.76	441.61	441.57	442.45	441.97
3	451.87	451.74	451.68	451.51	451.16
4	441.84	441.67	441.55	441.30	440.74
5	441.04	441.07	440.94	440.92	440.87
6	439.99	439.92	439.64	439.54	439.31
7	451.00	450.95	450.96	450.84	451.38
8					
9	449.66	449.64	449.49	449.39	449.26
10	442.68	442.59	442.71	442.62	442.64
12	447.78	447.74	447.74	447.64	447.81
13	441.44	441.37	441.50	441.39	441.39
14	441.19	441.02	440.85	440.73	440.87
15	438.66	438.62	438.64	438.70	438.78

OBSERVATION WELL DATA

Well No.	12/8/69	12/17/69	1/30/70	2/2/70	2/21/70
1		445.40	445.39	445.35	445.30
2	441.7	441.61	442.03	441.97	442.19
3	451.11	450.97	450.90	451.20	451.37
4	441.32	440.81	440.57	435.13	441.22
5	440.92	440.82	440.83	440.83	440.82
6	439.23	439.20	439.15	439.16	439.12
7	450.62	450.60	450.76	451.42	452.50
8	442.06	442.87	449.53	447.14	446.09
9	451.05	448.98	451.41	451.48	450.53
10	442.81	442.73	442.58	442.83	442.88
12	447.85	447.79	448.47	449.05	448.83
13	441.45	441.38	441.25	441.53	441.53
14	440.27	440.03	440.06	440.04	439.45
15	438.78	438.74	439.11	439.13	439.07

OBSERVATION WELL DATA

Well No.	3/7/70	3/16/70	3/30/70	4/4/70	4/11/70
1	445.38	445.24	445.32	445.38	445.39
2	442.46	442.37		442.90	441.65
3	451.77	452.03	452.51	452.52	452.62
4	440.89	440.72	441.19	441.06	441.47
5	440.91	440.92	441.01	441.00	441.03
6	439.07	439.09	438.13	439.13	439.80
7	452.04	452.12	454.61	452.48	452.47
8	445.53	445.26	445.14	445.07	444.98
9	450.88	449.76	450.67	450.13	449.99
10	442.99	442.99	443.08	443.04	443.08
12	449.28	449.22	449.56	449.59	449.53
13	441.60	441.57	441.64	441.63	441.59
14	441.31	440.88	441.29	441.18	441.34
15	439.06	439.04	439.00	439.01	438.89

OBSERVATION WELL DATA

Well No.	4/17/70	4/24/70	5/1/70	5/9/70	6/11/70
1	445.60	Dry	445.34	445.36	445.35
2	442.32	442.36	442.39	442.51	441.00
3	452.52	452.49	452.49	452.57	453.20
4	441.58	441.50	441.57	441.61	443.16
5	441.00	440.94	440.93	440.98	440.96
6	439.98	440.00	439.93	439.83	440.13
7	452.44	452.67	452.64	452.73	452.02
8	444.89	444.81	444.72	444.43	444.33
9	449.95	449.92	449.93	449.72	449.83
10	443.01	442.81	443.00	443.00	443.11
12	449.42	449.47	449.45	449.43	448.85
13	441.50	441.56	441.57	441.33	441.67
14	441.06	441.13	441.02	441.10	441.53
15	438.84	438.82	438.82	438.70	438.68

OBSERVATION WELL DATA

Well No.	7/2/70	7/20/70
1	444.95	445.69
2	441.63	441.88
3	451.95	451.95
4	443.34	444.29
5	440.62	440.97
6	439.69	440.00
7	451.19	453.21
8	443.81	444.15
9	449.39	449.71
10	442.54	442.80
12	437.93	448.04
13	441.07	441.39
14	430.89	431.11
15	438.39	438.76

APPENDIX XI-H

ANALYSES OF SUBSURFACE DRAINAGE FROM VEGETATIVE TEST PLOTS

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General Notes

1. Subsurface drainage pipes and sampling ports installed on Test Plots 3, 4, 5, 6, 7, 8, 9, 10, 12, and 13.
2. Sampling ports on Test Plots 5, 6, 12, and 13 were always dry.

TEST PLOT NO. 3 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/16	1.4	47,100	27,000	14,320	5,170	45,600
1/27	1.5	22,200	16,120	6,250	1,140	19,900
2/23	1.55	27,250	17,350	7,660	2,435	21,650
3/7	1.8	18,600	14,350	5,130	1,920	19,400
3/11	1.8	23,000	16,800	6,475	3,060	2,345
3/19	1.35	20,100	15,100	5.600	1,765	20,450
3/27	1.7	20,000	15,900	5,360	1,790	21,000
4/4	2.1	21,750	14,450	6,450	2,730	24,500
4/9	1.65	20,600	15,800	6,400	2,920	22,000
4/15	1.8	18,600	14,550	5,240	1,790	19,800
4/22	1.8	16,000	15,120	4,550	1,430	17,380
4/30	1.6	18,000	16,150	5,150	1,755	19,600
5/7	1.8	19,100	17,100	2,460	1,030	20,200
5/15	1.55	19,300	17,250	4,860	2,065	17,650
5/21	1.6	18,100	19,600	5,650	2,795	19,700

TEST PLOT NO. 4 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/16	2.2	19,300	36,000	6,880	6,230	19,200
1/27	2.0	5,230	5,700	1,361	201	6,250
2/23	2.15	8,050	8,300	2,390	1,430	8,940
3/7	2.2	6,930	7,950	1,875	1,150	7,775
3/11	2.6	11,500	7,500	2,200	1,595	8,650
3/19	2.0	7,720	6,950	2,460	1,645	8,900
3/27	2.0	5,850	7,000	1,565	643	6,730
4/4	2.5	6,760	6,950	2,260	1,630	8,160
4/9	2.35	6,800	7,400	2,360	1,890	7,730
4/15	2.2	10,400	10,900	3,130	2,500	11,230
4/22	2.6	11,300	11,870	3,620	2,430	12,580
4/30	2.1	11,800	11,650	4,110	3,240	13,550
5/7	2.35	17,300	11,090	1,880	1,460	13,450
5/15	1.9	15,900	15,000	5,260	3,915	17,000
5/21	1.9	15,600	16,800	5,480	4,190	17,650

TEST PLOT NO. 7 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/27	1.3	21,300	17,650	4,800	413	20,700
2/11	1.3	40,000	23,500	8,850	1,609	38,400
2/23	1.3	34,600	22,400	8,300	1,485	30,350
3/7	1.6	55,000	32,100	15,520	11,050	56,650
3/11	1.5	53,500	28,000	14,100	9,050	5,075
3/19	1.2	17,900	17,500	3,880	470	18,550
3/27	1.3	41,400	26,700	10,000	4,580	41,800
4/4	1.95	28,800	17,700	7,470	4,360	33,100
4/9	1.8		21,200	9,400	6,590	
4/15	1.8	29,900	18,200	7,730	4,950	32,700
4/22	2.1	5,400	7,220	1,140	380	5,660
4/30	1.85	5,400	7,680	1,255	555	6,900

TEST PLOT NO. 8 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
2/1	1.1	60,500	34,650	16,320	7,670	56,600
2/23	1.4	28,400	18,750	7,130	3,580	28,000
3/7	1.35	57,000	36,700	15,850	8,480	60,300
3/7		36,000		10,110	5,320	37,400
3/19	1.45	12,050	11,650	2,580	470	12,490
3/27	1.1	40,600	33,500	11,500	5,200	46,000

TEST PLOT NO. 9 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/27	1.1	32,500	26,400	8,400	4,160	20,300
2/1	1.3	40,450	29,100	12,900	5,720	43,200
2/23	1.35	29,350	20,200	7,260	3,510	29,350
3/7	1.4	36,600	33,350	12,100	5,780	50,700
3/11	1.2	54,000	35,900	14,225	9,200	48,000
3/19	1.6	6,230	7,950	1,320	100	7,000
3/27	1.2	40,050	29,700	9,400	4,220	39,410
4/4	1.6	36,500	30,000	11,250	8,530	43,700
4/15	1.55	38,400	28,000	10,780	5,860	39,400

TEST PLOT NO. 10 SUBSURFACE DRAINAGE

Date 1970	pH	Net Acidity mg/l	Conductivity Micromhos per cm	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/16	1.2	40,600	16,200	11,290	8,400	39,350
1/27	1.4	12,150	13,650	2,860	1,852	12,500
2/11	1.8	10,300	14,900	3,130	2,150	12,950
2/23	1.6	11,350	12,200	2,320	1,515	11,320
3/7	1.6	24,900	24,400	6,060	4,250	27,350
3/11	1.3	32,000	27,750	7,870	5,600	32,200
3/19	1.8	4,550	7,830	1,025	536	5,380
3/27	1.3	21,000	22,400	5,040	3,870	21,500
4/4	1.65	24,750	22,400	6,180	4,600	28,800
4/9	1.15	40,000	35,900	10,200	8,300	40,800
4/15	1.2	42,700	40,300	10,850	8,920	42,600
4/22	1.4	30,500	32,500	7,670	5,730	31,600
4/30	1.1	44,750	42,500	11,710	10,050	47,100
5/7	1.3	43,800	42,000	4,730	4,120	45,500
5/15	1.1	38,900	39,400	10,170	8,560	40,400

APPENDIX XI-I

ANALYSES OF REFUSE SAMPLES AT INTERFACE OF VEGETATIVE TEST PLOTS

General Notes

1. Solid samples taken from Test Plots 1, 2, 7, 8, 9, 10, 12, 13, and 14 only.
2. Samples were taken at the interface between the cover and refuse or from the first 4 inches of refuse in plots having no cover.
3. Three solid samples, each weighing approximately 1 lb, were taken from each test plot and mixed together. A 100 gm sample was then taken from the composite, mixed with 500 ml of distilled water and allowed to settle for 10 minutes. The clear supernatant was then analyzed.
4. Minus net acidity values denote alkalinity, to phenolphthalein end point.

TEST PLOT NO. 1 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.75	1,000	174	9	2,065
1/12	2.62	1,230	221	3	2,280
1/15	2.45	1,875	353	4	2,710
3/10	3.7	400	60	56	1,630
3/23	3.0	450	74	45	1,345
3/31	4.3	-40	4	0	1,175
4/7	4.8		23	4	1,440
4/14	3.35	-570	21	4	768
4/22	6.0	-30	49	0	2,015
4/29	5.5	-50	18	0	1,345
5/4	6.45	-80	0	3	1,490
5/13	6.5	-50	20	0	1,265
5/21	8.2	-160	45		2,880
5/27		-60	45	0	1,536
6/5		-120	25	0	2,500
6/12	5.1	-50	4	0	1,390
6/18	7.0	-60	36	0	1,535
6/26	3.6	200	31	4	1,585

TEST PLOT NO. 2 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.5	2,050	393	2	1,920
4/7	2.7	475	49	3	1,630
4/14	3.1	500	45	4	1,820
4/22	6.2	-10	10	0	1,680
4/29	5.2	-80	27	4	2,545
5/4	6.4	-80	4	0	1,585
5/13	7.4	-60	23	22	1,480
5/21	7.5	-70	45		3,740
5/27		-110	25	8.9	1,680
6/5		-170	25	2	2,980
6/12	3.3	425	45	2	1,315
6/18	6.1	-70	25	18	1,535
6/26	4.0	130	16	4	1,730

TEST PLOT NO. 7 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.3	1,400	150	2	2,350

TEST PLOT NO. 8 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.3	1,625	165	18	2,470
1/12	2.51	1,300	140	11	1,625
1/15	2.6	900	144	22	1,367
3/10	2.25	2,100	373	58	3,120
3/23	2.55	950	134	11	2,140
3/31	2.7	450	27	7	865
4/7	2.55	700	74	18	1,705
4/14	2.9	1,400	159	54	1,490
4/22	2.5	1,700	329	24	2,930
4/29	2.6	720	69	11	1,105
5/4	2.25	2,300	332	38	3,170
5/13	3.0	-280	13	4	1,632
5/21	2.5	980	168	40	5,140
5/27		800	112	56	1,392
6/5		2,600	512	45	6,250
6/12	2.4	390	22	4	529
6/18	2.3	1,800	326	112	2,690
6/26	2.35	1,770	391	206	2,400
7/8	2.5	800	29	7	2,110

TEST PLOT NO. 9 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.3	1,950	458	145	1,920
1/12	2.45	1,525	192	56	2,110
1/15	2.35	1,850	328	11	2,470
3/10	3.7	400	60	56	1,630
3/23	2.3	1,200	173	46.0	1,680
3/31	2.4	2,500	484	196.5	3,200
4/7	2.1	3,110	626	236	4,280
4/14	2.35	1,775	313	120.5	2,880
4/22	2.3	2,950	606	159	4,130
4/29	2.65	1,200	192.5	94	1,440
5/4	2.3	1,550	216.5	122.9	2,400
5/13	2.25	1,720	306	172	2,420
5/21	2.2	2,840	583	148	8,260
5/27		1,500	281.5	180.6	2,112
6/5		1,300	208	80.6	2,120
6/12	2.3	1,300	266	184	1,535
6/18	2.35	1,300	197	145	1,975
6/26	2.5	900	125	17.9	1,780
7/8	2.2	2,700	508	161	3,170

TEST PLOT NO. 10 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.45	2,800	243	67	2,300
1/12	2.37	1,920	244	88	2,800
1/15	2.4	1,700	275	18	2,330
3/10	2.1	1,650	297	163	2,305
3/23	2.45	1,050	175	96	1,875
3/31	2.4	1,150	186	60	1,895
4/7	2.4	1,550	288	159	1,920
4/14	2.75	1,575	261	57	2,260
4/22	2.4	1,425	263	167	2,640
4/29	2.65	1,000	139	92	1,730
5/4	2.5	1,850	243	166	2,980
5/13	2.4	1,180	199	159	1,825
5/21	2.1	2,240	456	313	7,350
5/27		950	181	114	1,584
6/5		1,200	172	114	2,690
6/12	2.3	1,000	193	145	1,585
6/18	2.75	400	31	7	913
6/26	2.65	750	113	74	1,151
7/8	2.4	1,600	231	170	1,920

TEST PLOT NO. 12 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.15	6,300	1,445	415	7,520
1/12	2.25	1,355	540	141	2,045
1/15	2.7	2,150	465	161	3,070
3/10	2.35	2,850	536	380	3,405
3/23	3.25	300	25	16	1,008
3/31	2.5	1,200	172	82.8	2,450
4/7	3.3	600	76	65	1,705
4/14	3.0	1,050	117	67	2,420
4/22	3.2	-390	29	18	1,825
4/29	3.05	404	31	9	1,200
5/4	3.9	2,750	36	13	1,540
5/13	3.0	320	34	20	1,075
5/21	2.7	670	114	105	3,120
5/27		1,300	199	83	9,600
6/12	2.5	1,000	244	181	1,680
6/26	2.55	1,300	253	74	1,585
7/8	2.2	4,000	754	286	3,700

TEST PLOT NO. 13 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.5	1,550	247	4	2,300
1/12	2.47	2,360	236	17	2,120
1/15	2.45	2,650	578	83	3,600
3/10	2.35	2,850	536	380	3,405
3/23	4.3	250	6	2	1,490
3/31	5.7	-60			673
4/7	5.1		13		1,225
4/14	3.35	-700	9	4	1,055
4/22	4.35	-160	17.8	9	2,115
4/29	4.15	200	26.8	11	1,390
5/4	5.2	-180	9	2	1,780
5/13	6.4	-10	11	0	673
5/21	3.5	880	98	9	4,502
5/27		1,100	67	13	2,640
6/5		-460	58	7	2,880
6/12	5.4	-30	29	0	1,005
6/26	2.9	500	27	4	1,055
7/8	3.6	40			865

TEST PLOT NO. 14 SOLID SAMPLE

Date 1970	pH	Net Acidity mg/l	Total Iron mg/l	Ferrous Iron mg/l	Sulfate mg/l
1/6	2.6	2,750	386	60	2,850
1/12	2.8	1,740	271	13	2,390
1/15	2.55	2,200	509	24	3,165
3/10	5.3				3,700
3/23	3.75	450	43	38	1,490
4/7	5.8		11		1,370
4/14	2.6	4,700	726	74	4,220
4/22	4.3	500	1,640	150	2,160
4/29	3.7	160	27	13	816
5/4	4.1	-1,270	440	438	2,690
5/13	3.0	640	87	45	1,805
5/21	2.9	1,320	239	134	6,340
5/27		150	22	13	960
6/5		1,300	190	145	4,600
6/12	3.7	400	83	72	1,200
6/18	2.6	2,100	400	117	2,790
6/26	2.7	950	199	4	2,015
7/8	3.6	40			865

APPENDIX XI-J

ANALYTICAL PROCEDURES

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1. pH: Standard glass electrode pH meter.

2. Net acidity: ASTM D-1067 Method E, 1970.

3. Conductivity: Standard conductivity meter.

4. Total alkalinity: ASTM D-1067 Method B (methyl orange end point), 1970.

5. Total iron: Quantitative Analysis, H. Diehl and G. F. Smith, p. 292-3, John Wiley & Sons, Inc., 1955.

6. Ferrous ion: Ibid.

7. Sulfate: ASTM Benzidine Method for Sulfate (1946) with Modifications by Johnstone et al (C. 1959).

8. Soil test: The procedures used by the Agrico Chemical Division, Continental Oil Company for determining limestone and fertilizer requirements for grass plots established on soil covers are those recommended by the University of Illinois, Department of Agronomy, Urbana, Illinois. These procedures are as follows:

   pH: Soil plus water, measure with glass electrode and direct reading conductivity meter.

   Available Phosphorus: "P_1" test by Bray and Kurtz, Soil Science, 59:39 (1945).

   Exchangeable Potassium: C. A. Black et al. Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, Am. Soc. of Agronomy, Inc., Madison, Wisconsin (p. 1025-6).

   Exchangeable Calcium: Ibid, p. 894-5.

   Lime Requirement: McLean, Dumford and Coronel, Soil Science Society of America Proceedings, Vol. 30, No. 1, Jan.-Feb. 1966, p. 26-30.

APPENDIX XI-K

COST DATA FOR EXPERIMENTAL TEST PLOTS

PLOTS 1 AND 2

	$/A
Agricultural Limestone 40 T/A @ $5.50/T, spread	$220.00
Tilling limestone into refuse	6.00
Fertilizer, 6-24-24 0.75 T/A @ $55.30/T	41.48
Tilling fertilizer into refuse	3.00
Grass seed, rye and fescue 80 lb/A @ $24.00/cwt.	19.20
Grass seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours/A @ $4.50/man-hour	27.00
Total	$364.68
say	$365/A

PLOTS 3, 4, 5 AND 11

	$/A
Agricultural limestone 40 T/A @ $5.50/T, spread	$220.00
Disk limestone into refuse	6.00
Fertilizer, 6-24-24 0.75 T/A @ $55.30/T	41.48
Tilling fertilizer into refuse	3.00
Grass seed, rye and fescue 80 lb/A @ $24.00/cwt.	19.20
Grass seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours/A @ $4.50/man-hour	27.00
Total	$364.68
say	$365/A

PLOT 6

	$/A
Polyethylene plastic, 20 ft x 100 ft rolls 22 rolls/A @ $18.00/roll	$ 396.00
Labor to spread plastic 8 man-hours/A @ $4.50/man-hour	36.00
Soil, 4 inches thick 540 yd^3/A @ $1.00/yd^3	540.00
Lightweight equipment to spread soil without tearing plastic 540 yd^3/A @ $1.20/yd^3	648.00
Agricultural limestone 2 T/A @ $5.50/T, spread	11.00
Fertilizer, 6-24-24 0.5 T/A @ $55.30/T	27.65
Tilling limestone and fertilizer into soil	3.00
Grass seed, fescue 50 lb/A @ $24.00/cwt.	12.00
Grass seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours @ $4.50/man-hour	27.00
Total	$1748.65
say	$1749/A

PLOT 8

	$/A
Soil, 4 inches thick 540 yd^3/A @ \$1.00/yd^3	$540.00
Agricultural limestone 2 T/A @ $5.50/T spread	11.00
Fertilizer, 6-24-24 0.25 T/A @ $55.30/T	13.83
Tilling limestone and fertilizer	3.00
Grass seed, rye and fescue 70 lb/A @ $24.00/cwt.	16.80
Grass seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours @ $4.50/man-hour	27.00
Total	$659.63
say	$660/A

PLOT 9

	$/A
Soil, 12 inches thick 1613 yd^3/A @ \$1.00/yd^3	\$1613.00
Agricultural limestone 2 T/A @ \$5.50/T spread	11.00
Fertilizer, 6-24-24 0.25 T/A @ \$55.30/T	13.83
Tilling in limestone and fertilizer	3.00
Grass seed, rye, fescue, orchard grass 80 lb/A @ \$24.00/cwt.	19.20
Seed application	3.00
Straw mulch 1.5 T/A @ \$30.00/T	45.00
Mulch application 6 man-hours @ \$4.50/man-hour	27.00
Total	\$1735.03
say	\$1735/A

PLOT 10

	$/A
Soil, 24 inches thick 3226 yd^3/A @ $1.00/$yd^3$	$3226.00
Agricultural limestone 2 T/A @ $5.50/T spread	11.00
Fertilizer, 6-24-24 0.25 T/A @ $55.30/T	13.83
Tilling in limestone and fertilizer	3.00
Seed, fescue, orchard grass, lespedeza mix 55 lb/A @ $26.00/cwt.	14.30
Seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours @ $4.50/man-hour	27.00
Total	$3343.13
say	$3345/A

PLOT 12

	$/A
Dried sewage sludge, 4 inches thick 540 yd^3 @ 90 lb/ft^3 = 656 T/A @ 12 T/truckload = 55 loads/A @ 1.5 hr/load and $8.00/hr	$660.00
Sludge application 8 hours @ $10.00/hr	80.00
Grass seed, fescue and rye 20 lb/A @ $24.00/cwt.	4.80
Seed application	3.00
Straw mulch 1.5 T/A @ $30.00/T	45.00
Mulch application 6 man-hours @ $4.50/man-hour	27.00
Total	$819.80
say	$820/A

PLOT 16

	$/A
Agricultural limestone	
15 T/A @ $5.50/T spread	$ 82.50
Fertilizer	
Urea, 45-0-0 @ 200 lb/A @ $82.00/T	8.20
Phosphate, 0-46-0 @ 300 lb/A @ $77.00/T	11.55
Potas, 0-0-60 @ 300 lb/A @ $58.00/T	8.70
Fertilizer application	5.00
Grass seed, oats, fescue, sudangrass mix	
90 lb/A @ $24.00/cwt.	21.60
Straw mulch	
1.5 T/A @ $30.00/T	45.00
Mulch application	
6 man-hours @ $4.50/man-hour	27.00
Total	$209.55
say	$210/A

PLOT 17

	$/A
Coherex, 1:6 Coherex-water mixture @ 1 gal mixture/yd^2 or 807 gal. Coherex/A @ $0.42/gal.	$339.00
Self-propelled pressure sprayer vehicle and two tank trucks operating at 1 hr/A @ $49/hr	49.00
Total	$388.00
say	$388/A

1 Accession Number

2 Subject Field & Group

05B
05G

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 Organization

Truax-Traer Coal Company, A Division of Consolidation Coal Company,
Pinckneyville, Illinois

6 Title

Control of Mine Drainage from Coal Mine Mineral Wastes
Phase I - Hydrology and Related Experiments

10 Author(s)

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Ramsey, J. P.

16 Project Designation

Environmental Protection Agency Grant 14010 DDH

21 Note

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23 Descriptors (Starred First)

Mine drainage*, waste piles*, lagoons*, vegetative covers*, mineral wastes*, grasses, reclamation, acid mine drainage

25 Identifiers (Starred First)

Refuse piles*, slurry lagoons*, New Kathleen Mine*, Illinois, acid formation rate

27 Abstract

A project has been underway since 1968, at an abandoned mine located in southern Illinois, attempting to demonstrate practical means of abating pollution from coal mine mineral wastes. The site included a refuse pile occupying approximately 40 acres and a slurry lagoon complex of 50 acres.

The project consists of two phases. Phase I, reported herein, describes the characteristics and acid formation rate of the refuse pile. The average rate of acid formation for this refuse pile is 198 pounds of acidity, as $CaCO_3$, per acre per day. Acid contribution from the slurry lagoons was not determined but appears to be negligible.

As an abatement measure, a number of experimental vegetative covers were tested. Grass was successfully established with and without the use of topsoil, weathering well for one year. The long-term effects of establishing a grass cover directly on the refuse without the use of topsoil are not known at this time.

Phase II, currently in progress, will implement specific remedial procedures for the entire site, to be followed by a monitoring program that will determine the degree of pollution abatement. A final report covering Phase II will be submitted.

Abstractor Z. V. Kosowski

Institution Consolidation Coal Company

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